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Microcalorimeter for 7 mm Coaxial Transmission Line

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Microcalorimeter for 7 mm Coaxial Transmission Line

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TRADE NAMES AND SI UNITS DISCLAIMER

Certain commercial components used in the microcalorimeter are identified in this document in order to adequately specify the design. Such use and identification does not imply recommendation or endorsement by NIST, nor does it imply that the identified items are necessarily the best available for the purpose.

The International System of Units (SI) is used except in the dimensioned part drawings found in appendix B. The shop which made these parts was not equipped to use metric dimensions. Financial resources are not currently available to convert the drawings to SI units.

MICROCALORIMETER FOR 7 mm COAXIAL TRANSMISSION LINE

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Design, evaluation, and construction details are given for the coaxial microcalorimeter used by NIST as part of the microwave power standard in 7 mm coaxial transmission line. Two versions are described: one with a Type N connector and one with an APC-7 connector. The operating frequency range is 0.01 to 18 GHz with either connector. The microcalorimeter is used to measure the effective efficiency of a reference standard, which is then used to calibrate other microwave power sensors. These reference standards are thermistor mounts designed by NIST to be compatible with the microcalorimeter. Detailed microcalorimeter drawings and assembly instructions are included.

Key words: coaxial microwave power standard; microcalorimeter; microwave; microwave microcalorimeter; microwave power measurement; microwave power standard.

1. INTRODUCTION

1.1 NIST Microwave Power Standards

The microwave power standards in use at the National Institute of Standards and Technology (NIST) consist of microcalorimeters and associated reference standards [1-4]. Each power standard is made up of both a microcalorimeter and a reference standard. The reference standards are substitution type bolometric power detectors[1] which have been designed by NIST to give optimum performance with the microcalorimeters. Figure 1.1 shows the coaxial microcalorimeter and the Type N thermistor mount used as the reference standard [5]. References [1-5] include detailed descriptions of typical microcalorimeter and bolometer mount operation. However, for convenience a brief summary follows.

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[1]These detectors are generally called bolometer mounts or simply, mounts. In this document, the terms "reference standard," "bolometer mount," and "mount" are used interchangeably.

1.2 Bolometer Mount-Microcalorimeter Operation

The bolometric power detector uses a heat sensitive resistor (bolometer) which terminates the transmission line and absorbs the microwave energy. Two types of bolometers are used: a platinum wire with a positive temperature coefficient called a barretter, and a thermistor bead with a negative temperature coefficient. The detectors are biased by an external source of dc current (power meter) to an operating resistance that produces a match with the characteristic impedance of the transmission line. Coaxial mounts typically use two bolometer elements which are connected in series for the dc bias, but are in parallel for the rf. Thus, to match the 50 Ω characteristic impedance of a coaxial transmission line, the pair is maintained at a series resistance of 200 Ω. When microwave energy is applied to the mount, the dc bias supplied by the power meter is automatically reduced to maintain a constant operating resistance [6]. If all the microwave energy incident on the mount were absorbed by the bolometer elements and if the elements were heated identically by equal amounts of dc and rf power, then the microwave power would be equal to the amount by which the dc power is reduced. This is called a substitution type power meter, because the rf power replaces a portion of the dc bias power. The substituted dc power (also called the bolometric power) is calculated using the equation

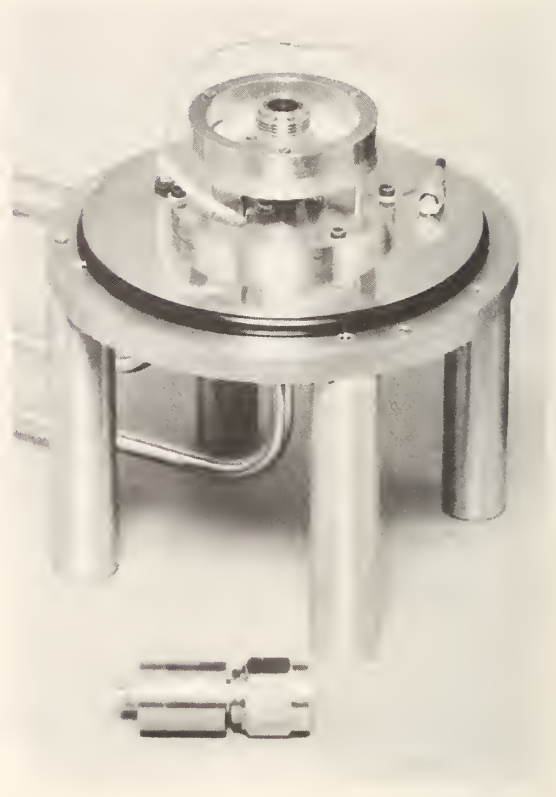


Figure 1.1 Coaxial microcalorimeter and coaxial reference standard.

$$P_{dc} = \frac{V_1^2 - V_2^2}{R_0}, \tag{1.1}$$

where V_1 is the power meter output voltage (the dc voltage across the bolometer elements) with no rf, V_2 is the power meter output voltage with rf, and R_0 is the dc operating resistance of the bolometer pair (200 Ω for a coaxial mount).

The microwave energy incident on a mount is not all absorbed by the bolometer elements. The dielectric and conductor losses in the input connector, the input transmission line, and the bolometer mounting structure result in a measurement error characterized by a correction factor called the mount efficiency. This correction is always less than 1. In addition, the bolometer elements are not heated identically by equal amounts of rf and dc power. This is known as the rf-dc substitution error. The combination of these two effects, which is measured by the microcalorimeter, is a correction factor defined as the effective efficiency η_e. The rf power absorbed by the mount is calculated by dividing the substituted dc power by the effective efficiency. The mount effective efficiency is independent of mismatch corrections, which are treated separately at the time of calibration transfer to an unknown mount.

The bolometer elements used in the reference standards are thermistors. Thermistors are rugged and resist burnout in the event of an rf overload. They are available commercially as a conveniently usable subassembly. Disadvantages to using thermistors include a continuous drift in the bias current even in a constant temperature environment. Also, thermistors are not usable in an alternative efficiency measurement technique known as the impedance method [7].

The microcalorimeter essentially measures the temperature rise of the bolometer mount connected to it. In the coaxial microcalorimeter, the temperature increase of the mount is measured with a thermopile. The measurement procedure determines the following at each frequency of interest: the power meter and thermopile output voltages (V_1 and e_1) with only dc applied to the mount, and then again (V_2 and e_2) with both rf and dc applied. The effective efficiency η_e is calculated at each frequency using the equation

$$\eta_e = g \frac{1 - \left(\frac{V_2}{V_1}\right)^2}{\frac{e_2}{e_1} - \left(\frac{V_2}{V_1}\right)^2}. \tag{1.2}$$

The term g is a frequency dependent correction factor for the microcalorimeter-bolometer mount combination. It is also called the calorimetric equivalence correction. The uncertainty in the effective efficiency measurement is determined primarily by the uncertainty in g. The determination of g is a major effort that is described in reference [8].

A typical reference standard calibration is done at approximately 125 frequencies from 50 MHz to 18 GHz. Even with the automated system described in reference [8], the measurement takes about 40 h. Figure 1.2 shows a typical thermopile output at a few frequencies. The value of η_e for one of the reference standards, measured at 125 frequencies, is shown in figure 1.3. The expanded uncertainty in the η_e measurement as a function of frequency is shown in figure 1.4. The uncertainty components have been combined using the RSS method (square root of the sum of the squares.)

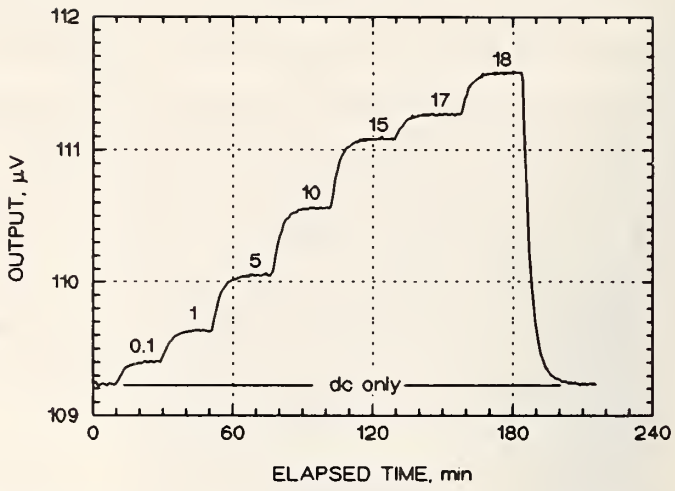


Figure 1.2 Thermopile output versus time for seven frequencies (in GHz).

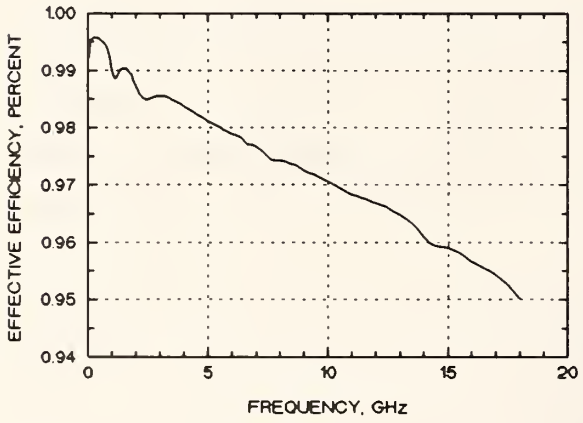


Figure 1.3 Effective efficiency of Type N mount measured at 125 frequencies.

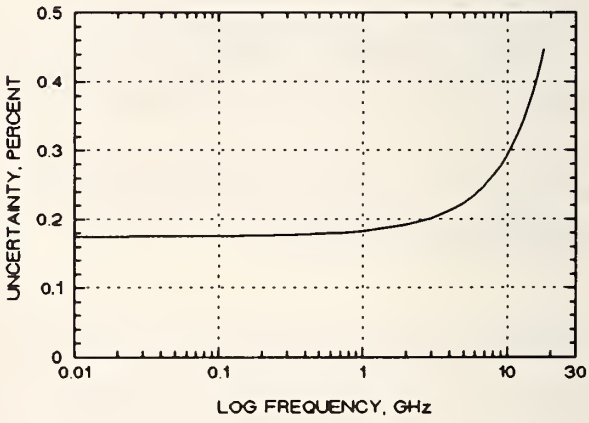


Figure 1.4 Expanded uncertainty for the Type N coaxial micro-calorimeter when measuring the effective efficiency of a NIST Type N mount.

2. DESIGN CONSIDERATIONS

As noted in the introduction, the primary function of the microcalorimeter is to measure the effect of all microwave energy dissipated in the reference standard bolometer mount. This is accomplished by using a thermopile to measure the temperature rise of the attached bolometer mount with respect to a thermal reference ring under two conditions. The first condition is with dc only dissipated in the bolometer mount and the second condition is with both dc and rf dissipated in the mount. Because the temperature changes are very small (on the order of 0.05°C), the microcalorimeter is also designed to be immersed in a stable temperature controlled water bath [9, 10] during the measurement to minimize the effect of external temperature changes. The water bath is controlled to about ± 20 μ°C at near room temperature.

Figure 2.1 is a partial cross sectional view of the entire calorimeter with the cover raised. When in use the unit is suspended in the temperature controlled water bath by the hanger extending from the top of the cover. The actual water level when the unit is in the bath is indicated.

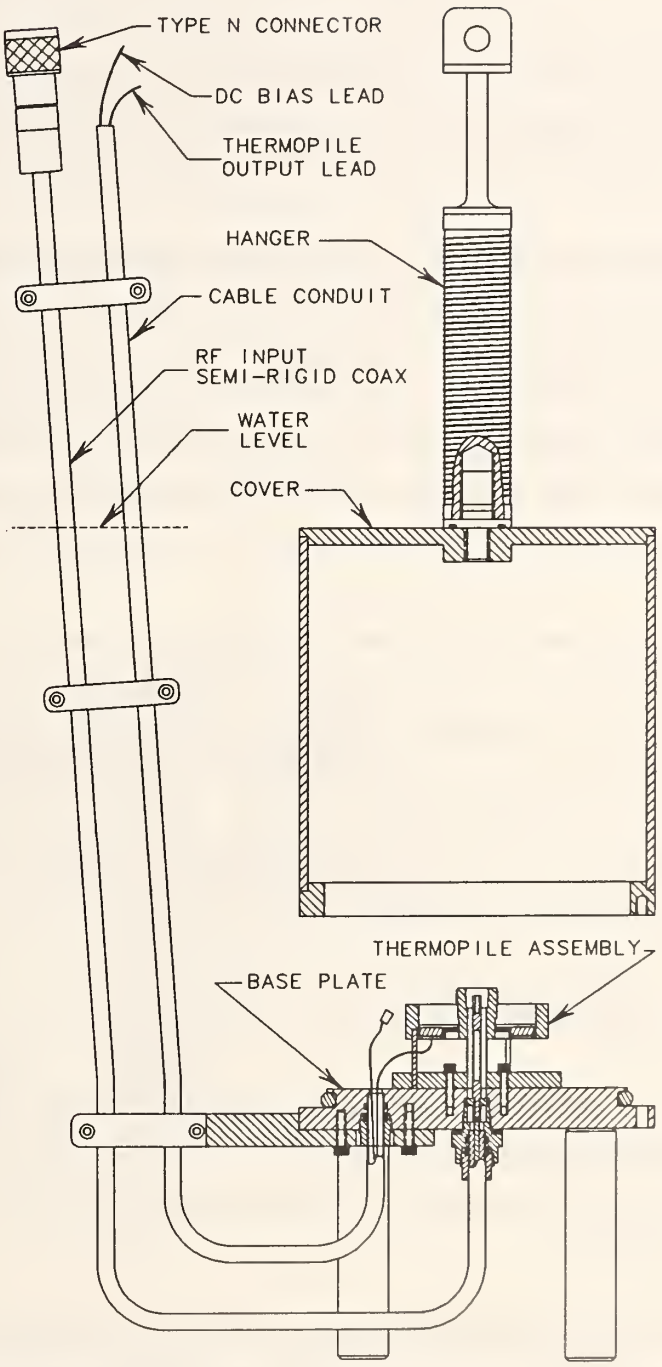


Figure 2.1. View of the entire microcalorimeter assembly.

2.1 Thermopile Assembly

This part contains a thermal isolation section as well as the thermopile itself. The thermal isolation section, which is between the baseplate (in close contact with the water bath) and the bolometer mount, allows the mount temperature to rise with respect to the baseplate. The isolation section is a short length of coaxial transmission line made with a thin-wall copper outer conductor and a hollow thin-walled gold-plated stainless steel inner conductor.

The thermopile is a ring made of 66 equally spaced radial turns of Constantan wire; the lower half of the ring is copper plated giving 66 copper/Constantan junctions around both inner and outer circumferences. The ring of inner thermocouple junctions is in thermal contact with (but electrically insulated from) the 7 mm coaxial outer conductor just below the coaxial connector. The circle of outer thermocouple junctions is in contact with a thermal reference ring which approximates the thermal characteristics of the dummy reference standard used in the earlier twin-joule microcalorimeter design as described in references [1] and [2].

The thermocouples in the thermopile are connected in series, so the thermopile output can be increased by increasing the number of junctions. The number of thermocouples in the original thermopile was limited by the input range, 100 μV, of the potentiometer used to measure the thermopile output. Since the microcalorimeter described here uses the original thermopile assembly, it has fewer thermocouple junctions than it would otherwise. A thermopile with many more junctions and made of finer wire would be a better match to the 2 mV range of the modern electronic nanovoltmeter now used.

2.2 Other Design Features

The rf input leads, the mount dc bias leads, and thermopile output leads are brought in through the bottom of the microcalorimeter. This provides a more convenient arrangement for removing the top cover and also keeps the leads in the water bath for a greater distance to provide better thermal tempering.

The entire assembly, including the cover, is gold plated for corrosion protection. The gold-plated interior of the cover is polished to provide a high infrared reflectance.

3. FABRICATION AND ASSEMBLY

3.1 Mechanical Design and Drawing Reference

Figure 3.1 shows a cross section of a portion of the Type N microcalorimeter with the major assemblies identified. Figure 3.2 is an exploded cross-sectional view of the same portion of the microcalorimeter with an identifier for each part as it is listed in the tables found with figure 3.3. Figure 3.3 is a view of the complete microcalorimeter with all the parts (except the dc bias and thermopile leads) identified. The parts that are obtained commercially are listed by letter in the upper table and with additional parts and detail in table A.1, appendix A. Those that must be fabricated are listed by item number in the lower table and with additional parts and detail in table B.1, appendix B. The table cross indexes the item with a part drawing which is identified by name and sheet number. All the dimensioned part drawings are found in appendix B in sheet number order. When viewed in the normal orientation, the sheet number is in the lower right corner.

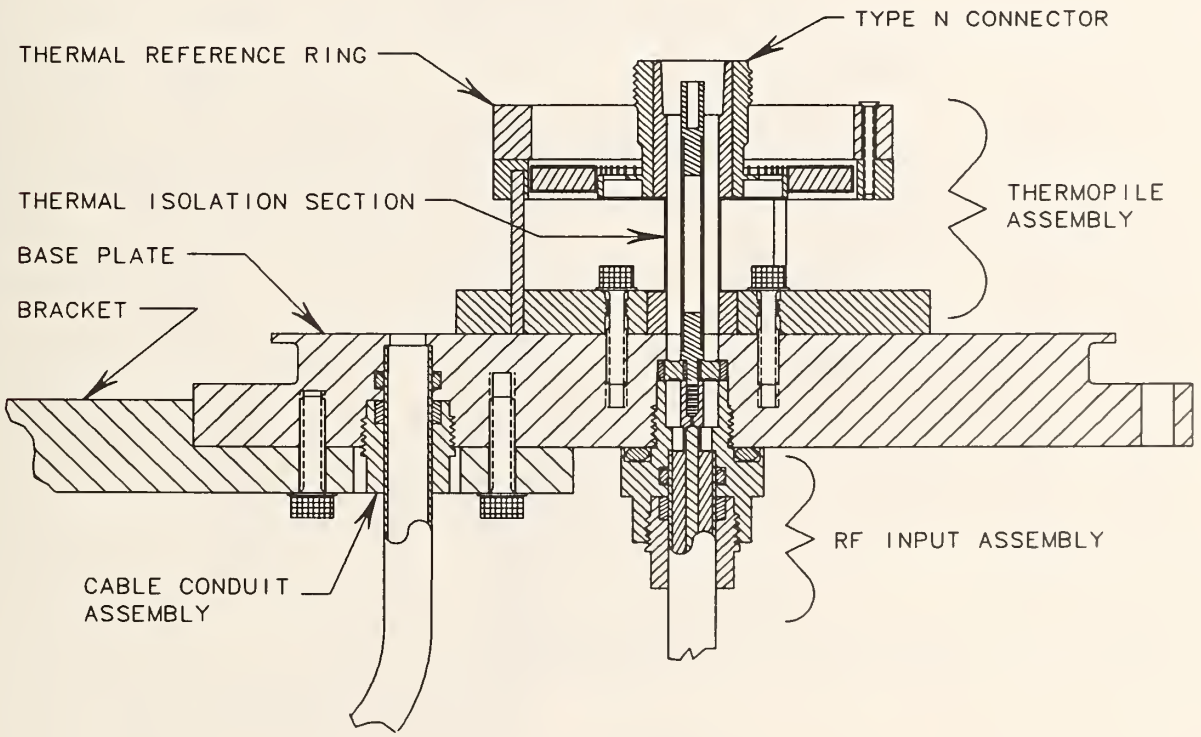


Figure 3.1. Cross section of the Type N microcalorimeter.

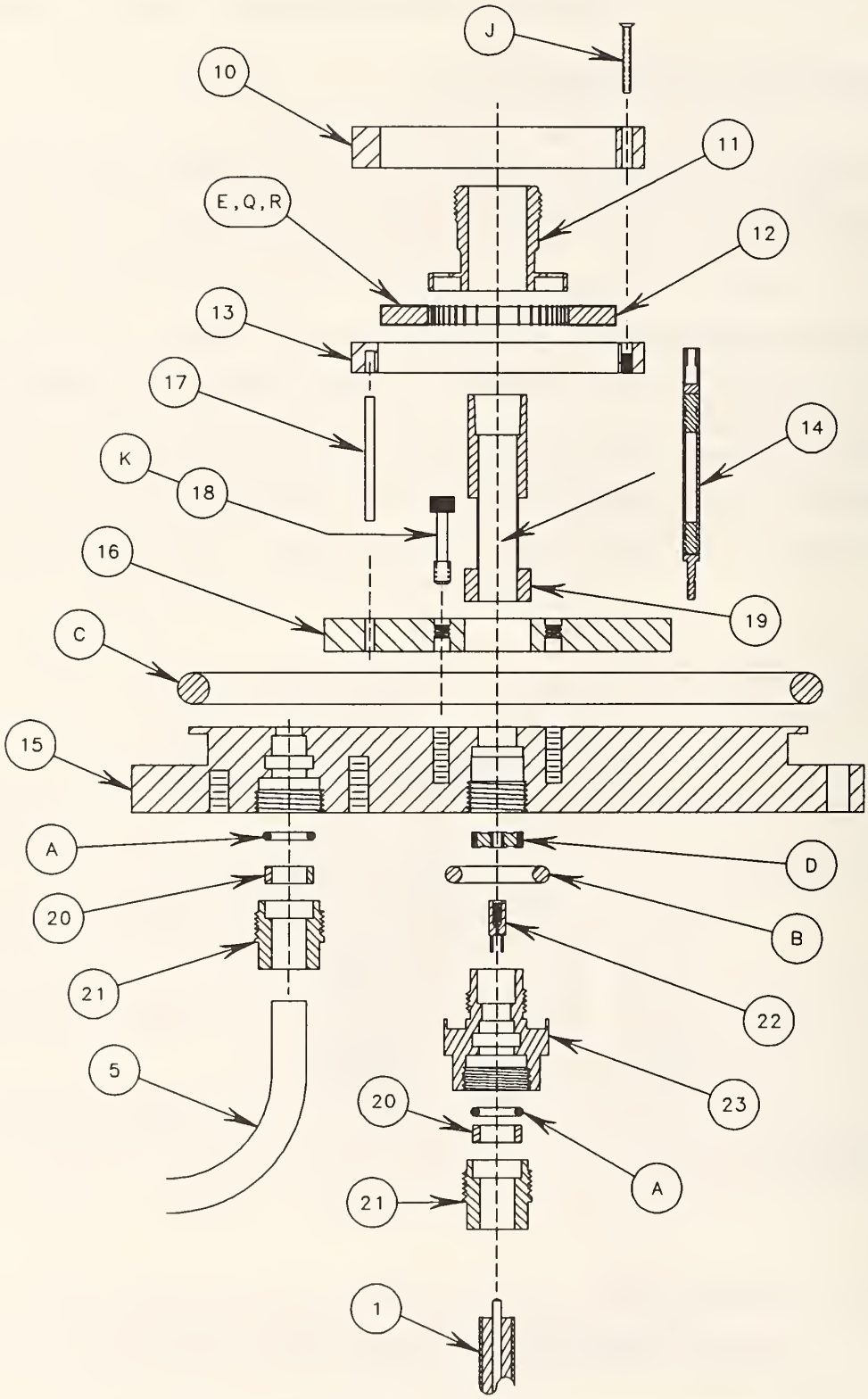
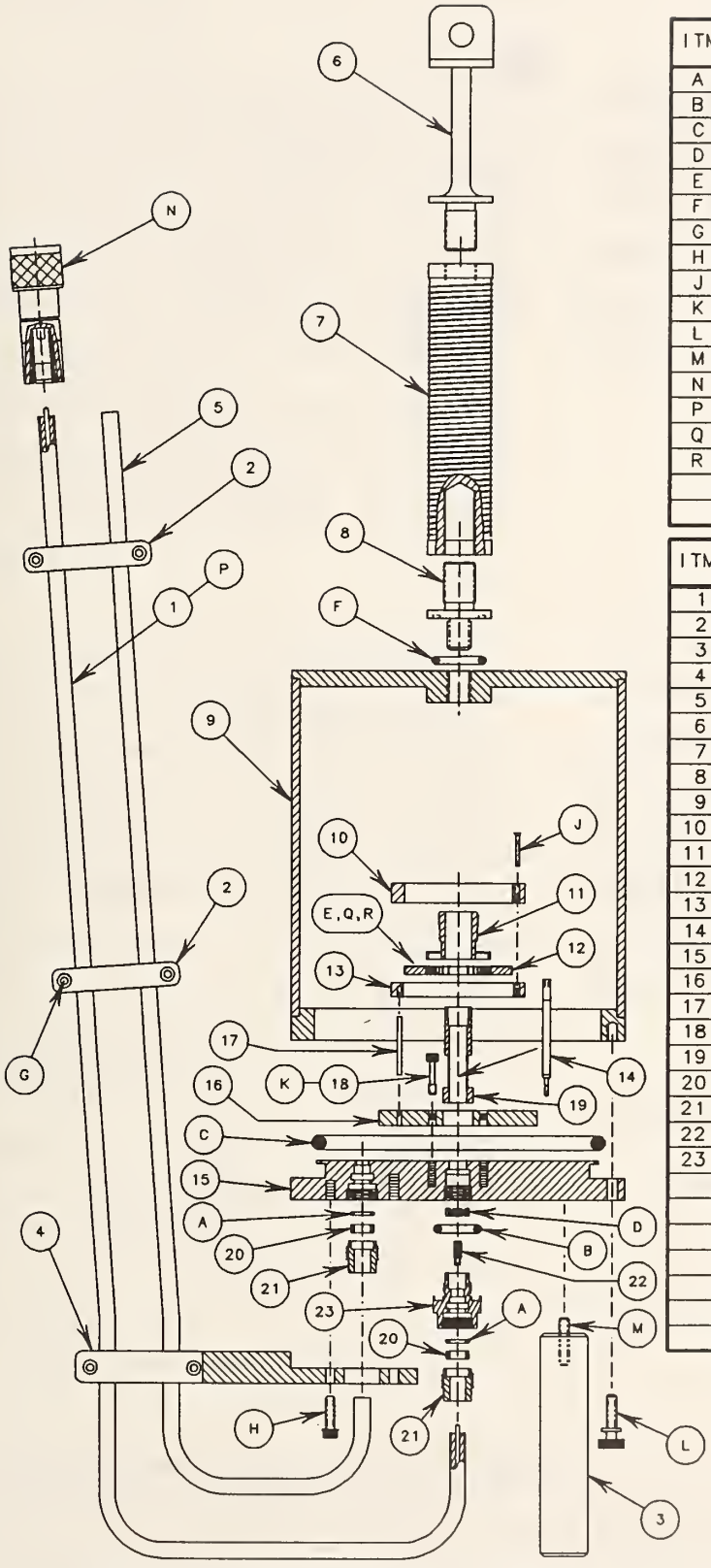


Figure 3.2. Exploded cross section of the base and thermopile with part identification.



ITM	DESCRIPTION
A	O-ring, Parker #2-010 (2 req'd)
B	O-ring, Parker #2-111
C	O-ring, Parker #2-346
D	Insulator, rf connector, H/P #5040-0306
E	Miniature socket, AMP #50462-6 (2 req'd)*
F	O-ring, Parker #2-015
G	4-40 X 1/4 hexagon socket screw (6 req'd)**
H	6-32 X 1/2 hexagon socket screw (2 req'd)**
J	0-80 X 1/2 flat countersunk screw (3 req'd)**
K	4-40 X 1/2 hexagon socket screw (8 req'd)**
L	8-32 X 1/2 knurled knob, brass (3 req'd)
M	8-32 X 3/4 SHSS, (4 req'd)**
N	Connector, type N, Amphenol #APC-N 131-10021
P	0.250, semi-rigid coaxial cable
Q	Pressure sensitive polyester tape*
R	Constantan wire, #30 AWG
	* NOT SHOWN IN FIGURE
	** STAINLESS STEEL

ITM	DESCRIPTION	DWG NAME	SHT NO.
1	RF input line	bp4_tub2	1
2	Upper & lower line spacer	bp4_br2	2
3	Leg (4 req'd)	bp4_br2	2
4	Lower clamp and bracket	bp4_br1	3
5	Cable conduit	bp4_tub1	4
6	Top hanger section	hanger	5
7	Center hanger section	hanger	5
8	Lower hanger section	hanger	5
9	Watertight cover	wcover	6
10	Thermal reference ring	cc1p_tr	7
11	Type N plug	cc1p_p	8
12	Thermopile form	cc1p_u	9
13	Thermal reference ring base	cc1p_v	10
14	Center conductor	cc1d_o	11
15	Baseplate	bp4_ba	12
16	Thermopile base	cc1p_r	14
17	Thermal ring standoff	cc1p_r	14
18	Modified 4-40 X 1/2 screw	cc1p_r	14
19	Thermal isolation section	cc1p_q	15
20	Input fastener ring	bp4_s	16
21	Input fastener nut	bp4_a	17
22	Input transition	bp4_c	18
23	RF input fastener	bp4_b	19
	Alignment tool*	alltool	20
	* NOT SHOWN IN FIGURE		

Figure 3.3. Drawing and part reference for the Type N microcalorimeter.

3.2 Assembly Details

The following section gives some suggestions regarding the assembly of the Type N coaxial microcalorimeter. The assembly of an APC-7 version would be essentially the same process. Most of the mechanical assembly can be carried out in a logical manner based on a careful study of the drawings.

3.2.1 Microcalorimeter Base

The microcalorimeter base consists of the baseplate (item 15), the legs, and the rf input and dc lead subassembly (items 1, 2, 4, and 5). After assembling the individual lines, the subassembly is put together according to the layout and dimensions shown in figure 3.4. Item 4, the lower clamp and bracket, is attached to the baseplate and then the subassembly can be fastened to the baseplate. Finally, the legs are attached to the baseplate.

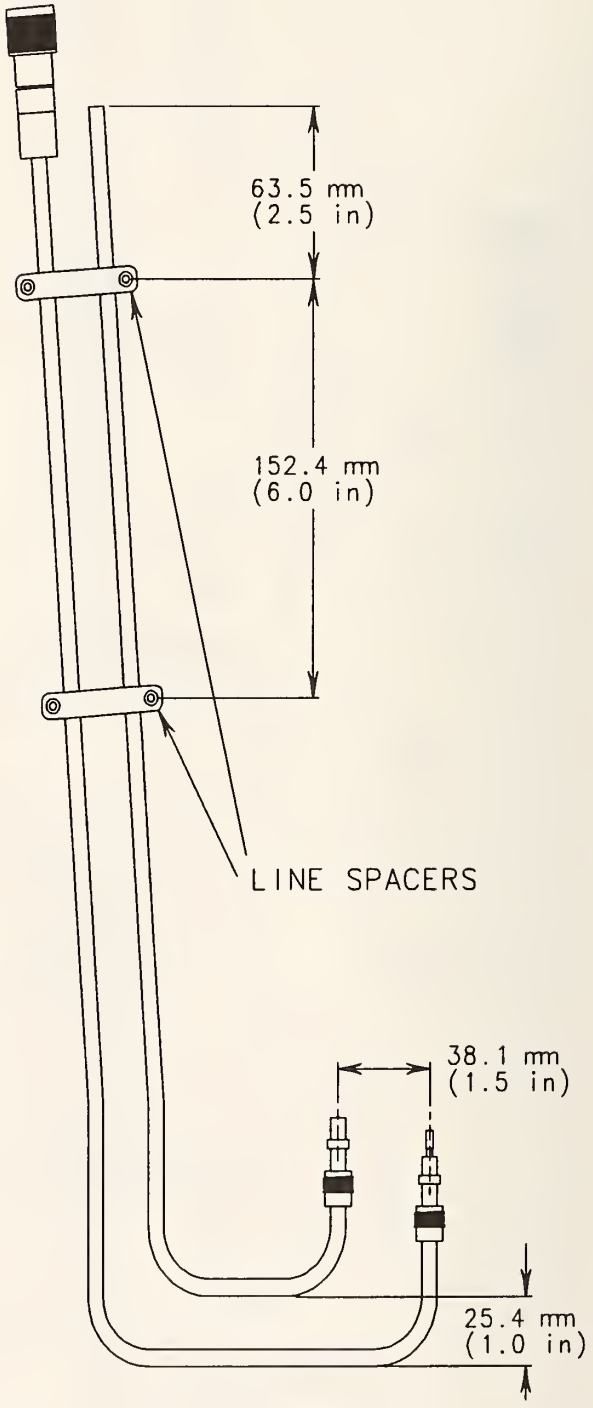


Figure 3.4. Rf input and dc lead subassembly.

3.2.2 Thermopile

The thermopile subassembly consists of items 10 through 14, and 16 through 19. For a cross- sectional view of those parts as assembled, refer back to figure 3.1. The threaded Type N connector part (item 11) and the base (item 16), are soldered to the outer conductor/thermal isolation section (item 19). The base for the thermal reference ring (item 13) is attached to the base by the standoffs (item 17).

Refer to figure 3.5. The thermopile form is wound with evenly spaced turns of Constantan wire (item R, table A.1). The ends of the wire are secured by looping the wire through the two holes in the form. The wires on the top half of the form are masked to prevent plating, and the exposed wire is copper plated for 30 min at a current of 100 mA. After removing the masking material, jacks (item E) are placed in the holes and soldered to the thermopile wire. The thermopile is pressed into place with an insulating film (item Q) on the inner and outer diameters.

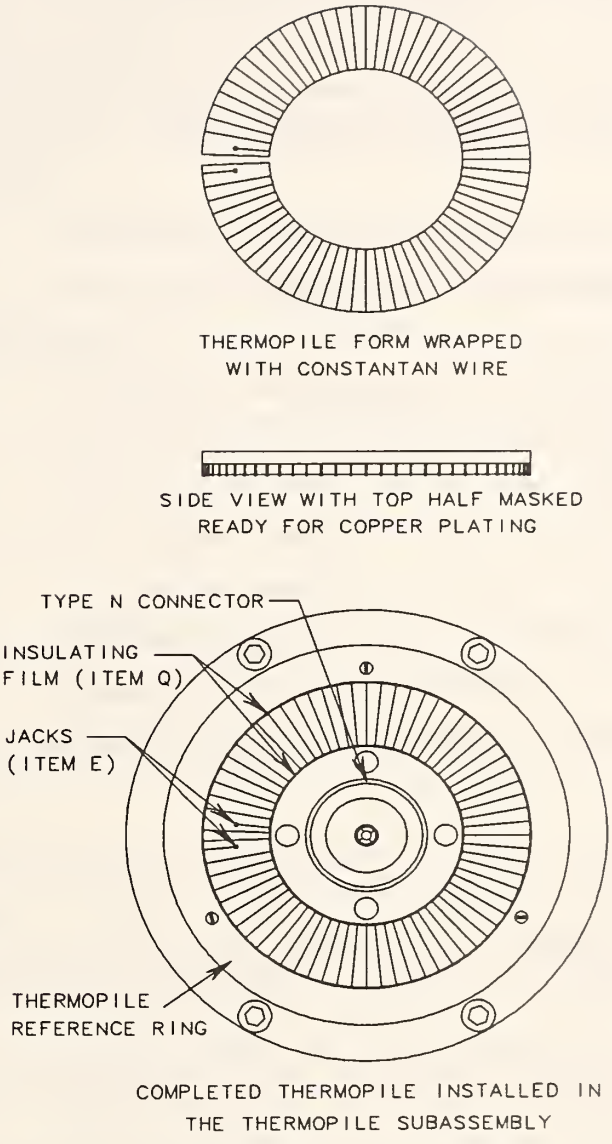


Figure 3.5. Thermopile top and side views.

The exact length of the stainless center conductor tube (part of item 14) is determined in the final stages of assembly. The tube is trimmed to give the final connector dimension shown in figure 3.6. Also shown in the figure is the nylon alignment tool (item 24, table B.1) that is used to make certain

the thermopile assembly is properly centered with the microcalorimeter baseplate before tightening the mounting screws (item 18).

3.2.3 Thermopile and Bias Leads

The thermopile output cable is made with shielded two-conductor cable (item S) with two small pins (item T, table A.1) that connect to the thermopile jacks. Thread this cable through the conduit (item 5), and then attach the custom made low thermal connector (for a Keithley model 181 nanovoltmeter). The special low thermal connector is identified as item 25 in table B.1 and shown in figure B21. The outer shell parts of the connector are listed in table A.1 as items U and V.

The dc bias lead is made of a 1 m length of the shielded four-conductor cable listed as item W in table A.1. The connector inside the microcalorimeter that attaches to the reference standard is item X. For the wiring pin-out see figure 3.7. The cable is threaded through the conduit before the custom Type IV power meter connector is put on the cable. This power meter connector is identified as item 26 in table B.1 and shown in figures B22 through B24.

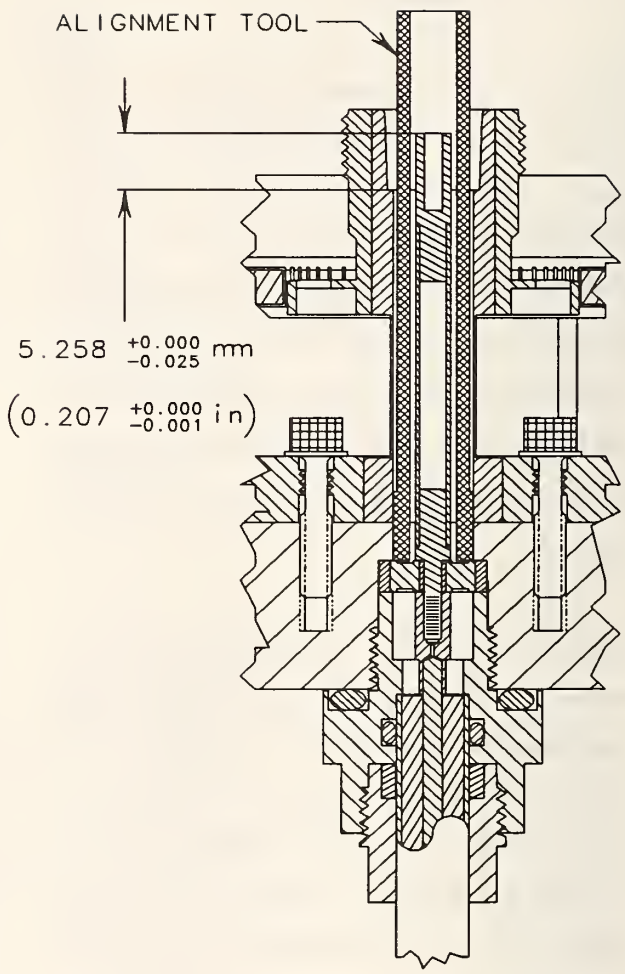


Figure 3.6. Connector dimension and alignment tool detail.

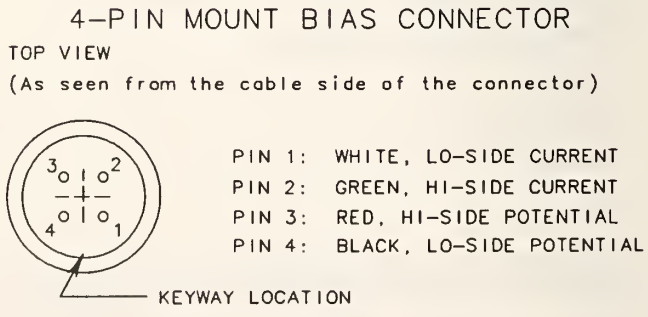


Figure 3.7. Pin-out for mount connector.

4. ACKNOWLEDGEMENTS

The first version of the coaxial microcalorimeter was designed and constructed by Morris E. Harvey. The microcalorimeter described in this document is based on that original design with some modifications. It uses the thermopile assembly from the original microcalorimeter. I also acknowledge the many helpful discussions and suggestions of Neil T. Larsen. Much of the drafting for the parts and other figures was ably provided by Paul G. Voris. The work was supported in part by the NIST calibration surcharge development fund.

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[10] Harvey, M.E. Precision temperature-controlled water bath. Rev. Sci. Instrum. 39(1): 13-18; 1968 January.

APPENDIX A. Parts List

The use of the particular components identified in the tables below does not imply recommendation or endorsement by NIST nor does it imply that the identified items are necessarily the best available for the purpose. Table A.1 identifies the parts and a manufacturer.

Table A.1. Commercial parts list

Part ID	No. needed	Part No., Description, Manufacturer
A	1	No. 2-010, O-ring Parker Seal Group, O-Ring Division, Lexington, KY 40512 (606) 269-2351
B	1	Parker No. 2-111, O-ring
C	1	Parker No. 2-346, 70D Nitrile O-ring
D	1	HP No. 5040-0306, insulator, rf connector Hewlett-Packard Co. - contact local sales office
E	2	No. 50462-6, miniature socket AMP Special Industries, Valley Forge, PA 19482 (215) 647-1000
F	1	Parker No. 2-015, O-ring
G	6	4-40 X 1/4 hexagon socket screw, stainless steel
H	2	6-32 X 1/2 hexagon socket screw, stainless steel
J	3	0-80 X 1/2 flat counter sunk screw, stainless steel
K	8	4-40 X 1/2 hexagon socket screw, stainless steel
L	3	8-32 X 1/2 knurled knob, brass
M	4	8-32 X 3/4 SHSS, stainless steel
N	1	No. APC-N 131-10021, Type N connector Amphenol Corp., RF/Microwave Operations, Danbury CT 06810 (203) 743-9272

Table A.1. Commercial parts list		
P	1	No. BA 5250, 0.250 semi-rigid solid dielectric coax Precision Tube Co., North Wales, PA 19454 (215) 699-5801
Q	-	Pressure sensitive polyester tape
R	-	#30 Constantan wire
S	1	Type 8640, #28 bare solid copper two-conductor shielded cable, 1 m long Belden Wire Co.
T	-	Type K24A/M gold-plated connector pin, 0.99 mm (0.039 in) diameter Vector Electronic Co.
U	-	No. MS-3106A-16-11P, connector shell Amphenol Corp.
V	-	No. 97-3057-1008, cable clamp Amphenol Corp.
W	1	No. NMVF4/30-404655, #30 AWG four-conductor shielded cable, 1 m long Cooner Wire Co.
X	1	DP-4S-1 straight plug, four-conductor miniature connector Microtech, Inc. Boothwyn, PA 19061 (215) 459-3566

APPENDIX B. Parts Drawings

Table B.1 cross references the fabricated parts to their drawing.

Table B.1. Fabricated parts list

Item No.	Description	No. needed	Figure number
1	Coaxial rf input line (RG-401/U) configuration	1	B1
2	Input lines spacer	2	B2
4	Microcalorimeter legs	4	B7
4	Lower bracket and clamp	1	B3
5	Cable conduit for dc input	1	B4
6	Top hanger section for cover	1	B5
7	Center hanger section for cover	1	B6
8	Lower hanger section for cover	1	B6
4	Watertight cover	1	B6
10	Thermal reference ring	1	B7
11	Type N connector and thermopile contact ring	1	B5
12	Thermopile form	1	B5
14	Base for thermal reference ring	1	B10
14	Center conductor assembly	1	B10
15	Microcalorimeter baseplate	1	B12, B13
14	Thermopile baseplate	1	B14
17	Thermal ring standoff	3	B14
18	Modified 4-40 X 1/2 screws	8	B14
19	Type N connector and thermal isolation section	1	B15
20	Fastener ring for input lines	2	B16
21	Fastener nut for input lines	2	B17
22	Center conductor transition	1	B18
23	Fastener for coaxial rf input	1	B19
24	Alignment tool	-	B20
25	Low-thermal-EMF connector	1	B21
26	NIST Type IV power meter connector	1	B22-B24

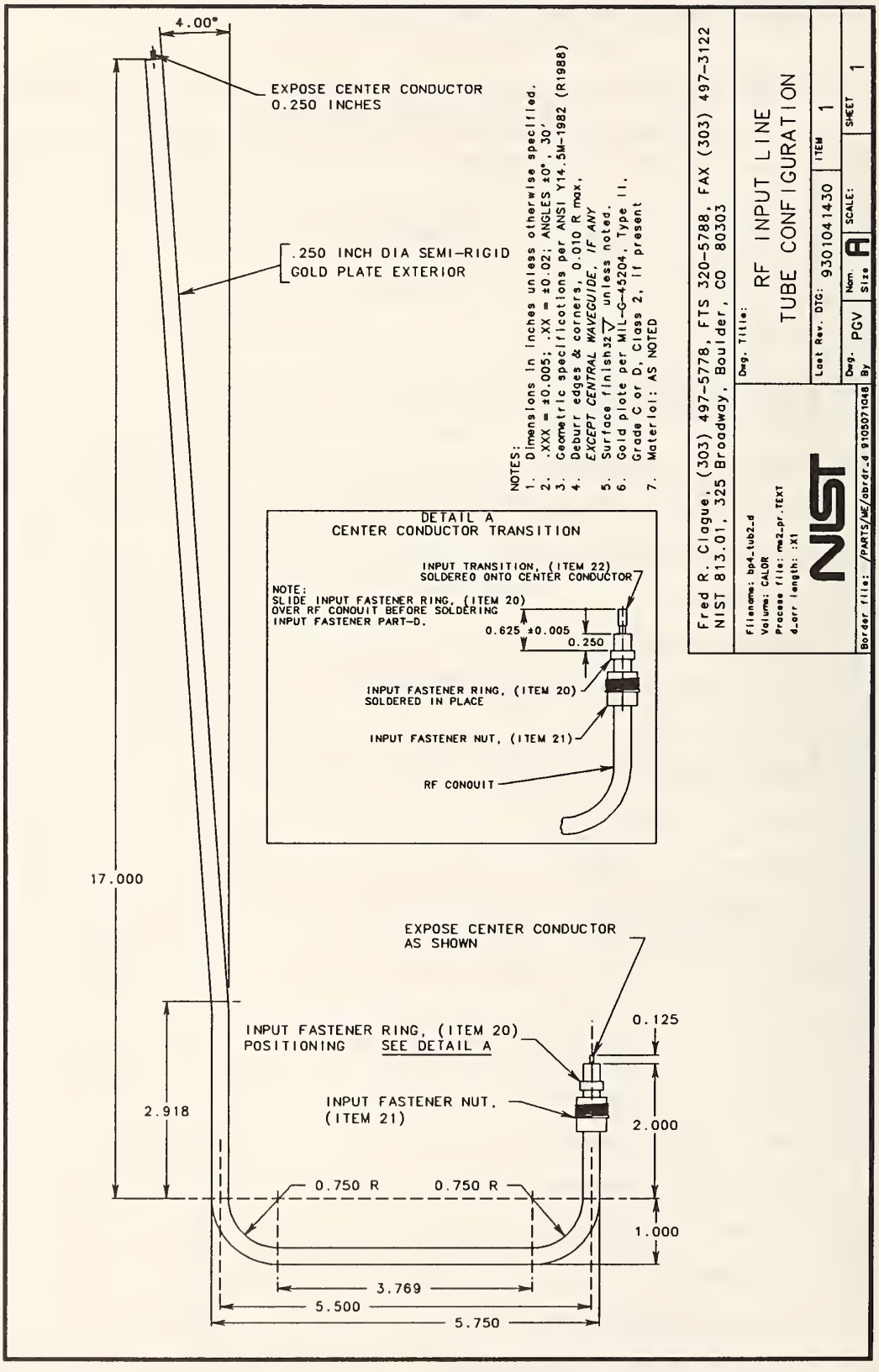

Figure B1. Coaxial rf input line configuration.

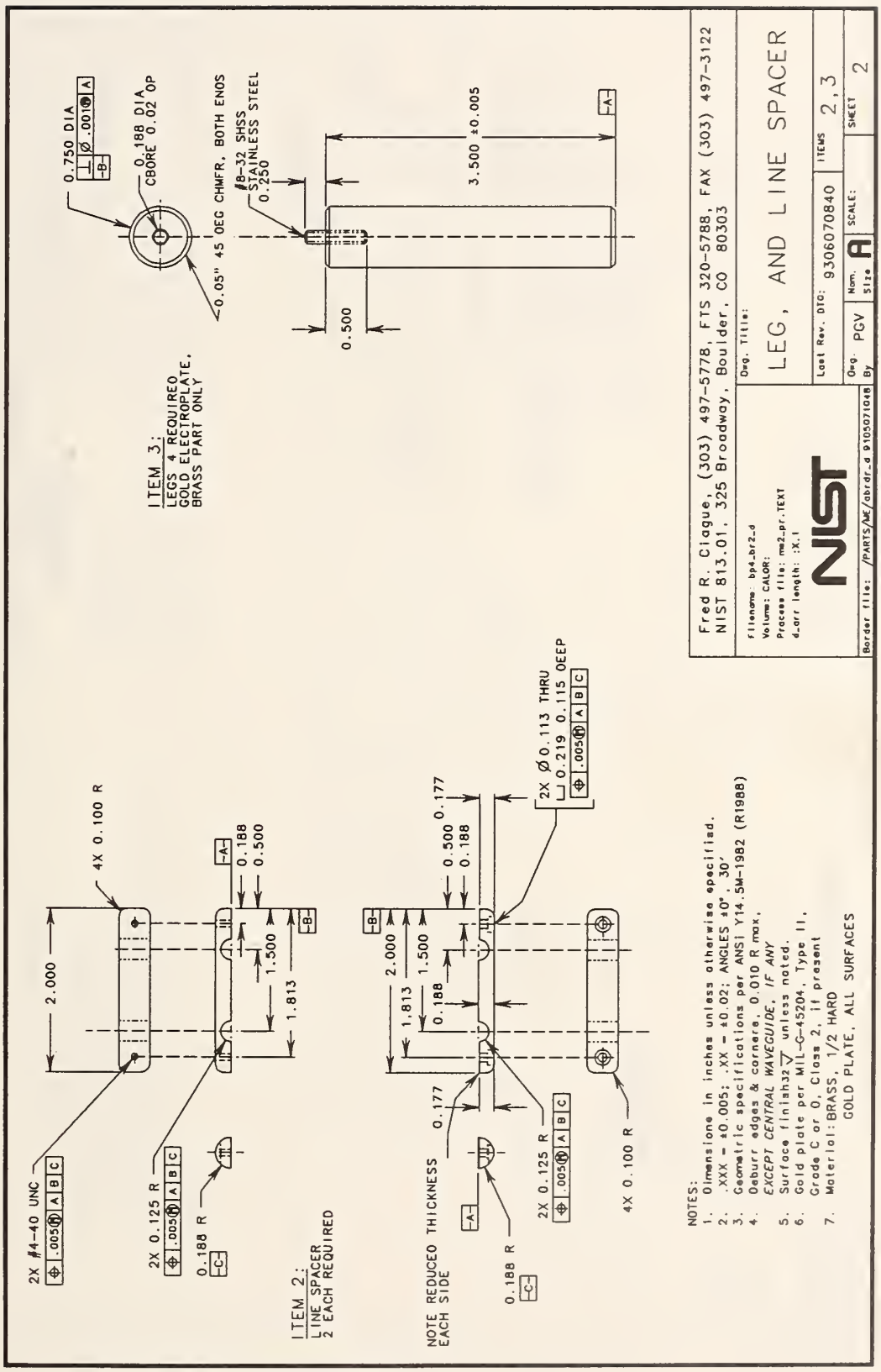

Figure B2. Input lines spacer and microcalorimeter legs.

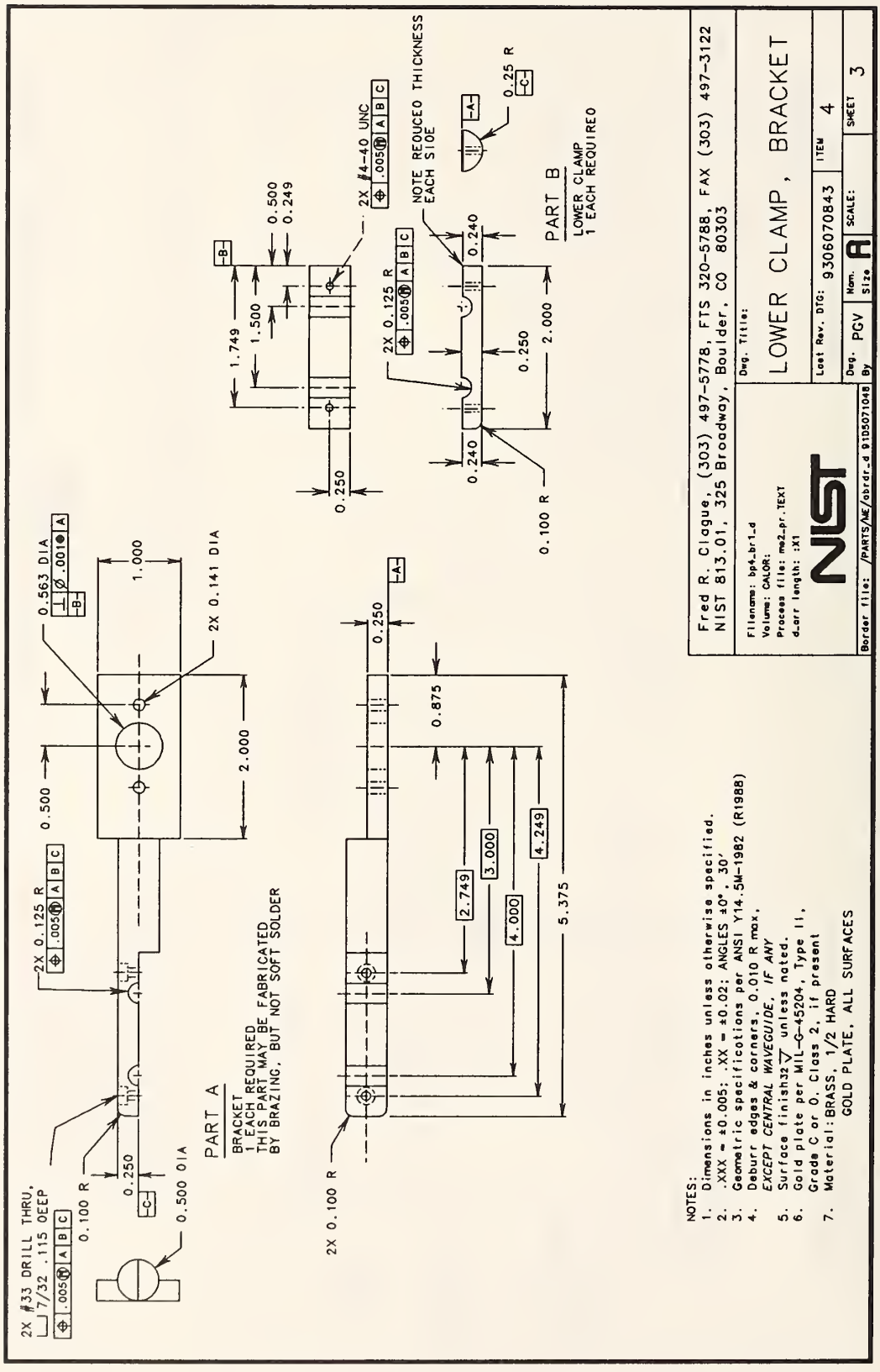

Figure B3. Lower bracket and clamp for input lines.

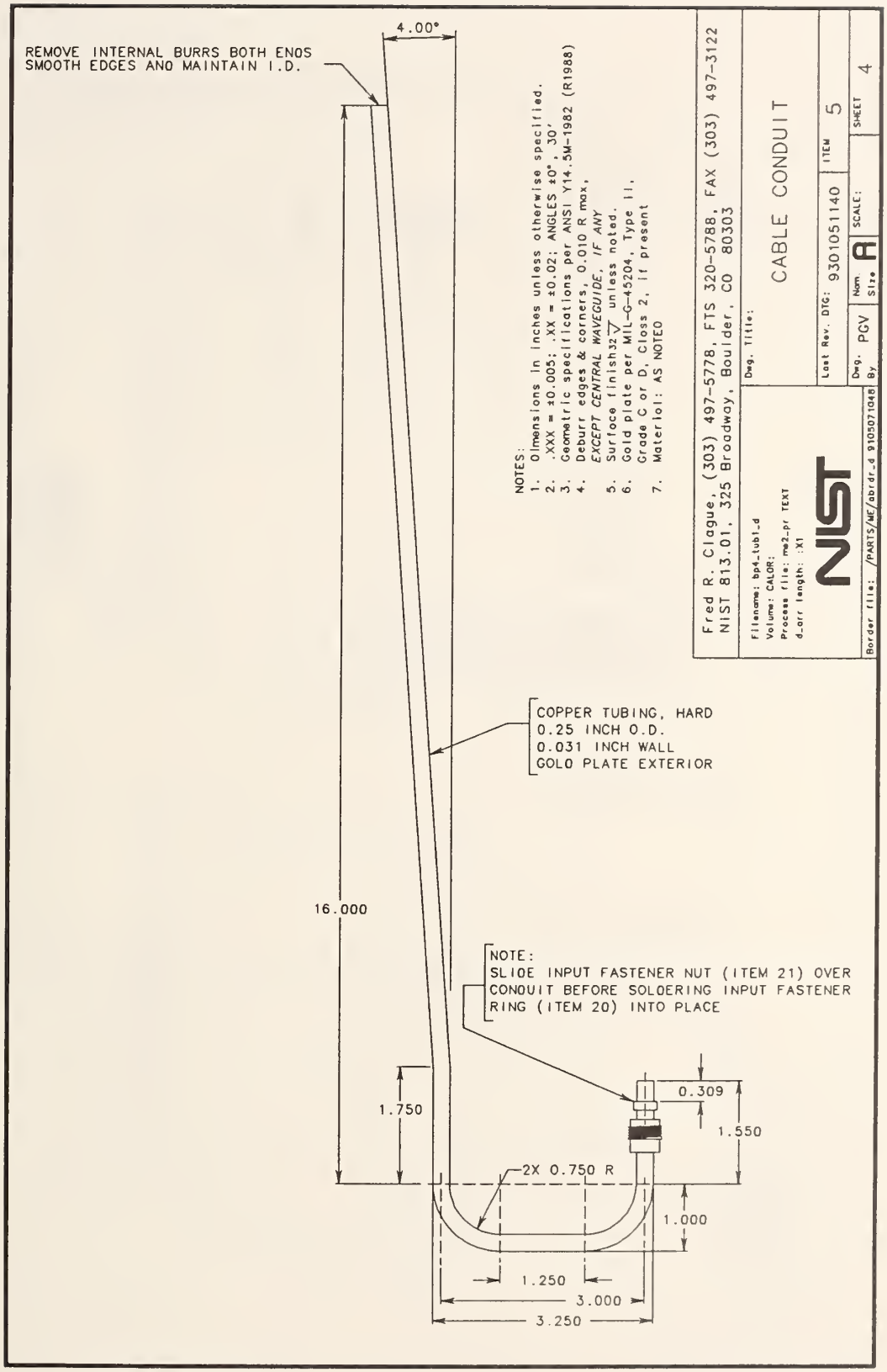

Figure B4. Conduit for dc cables.

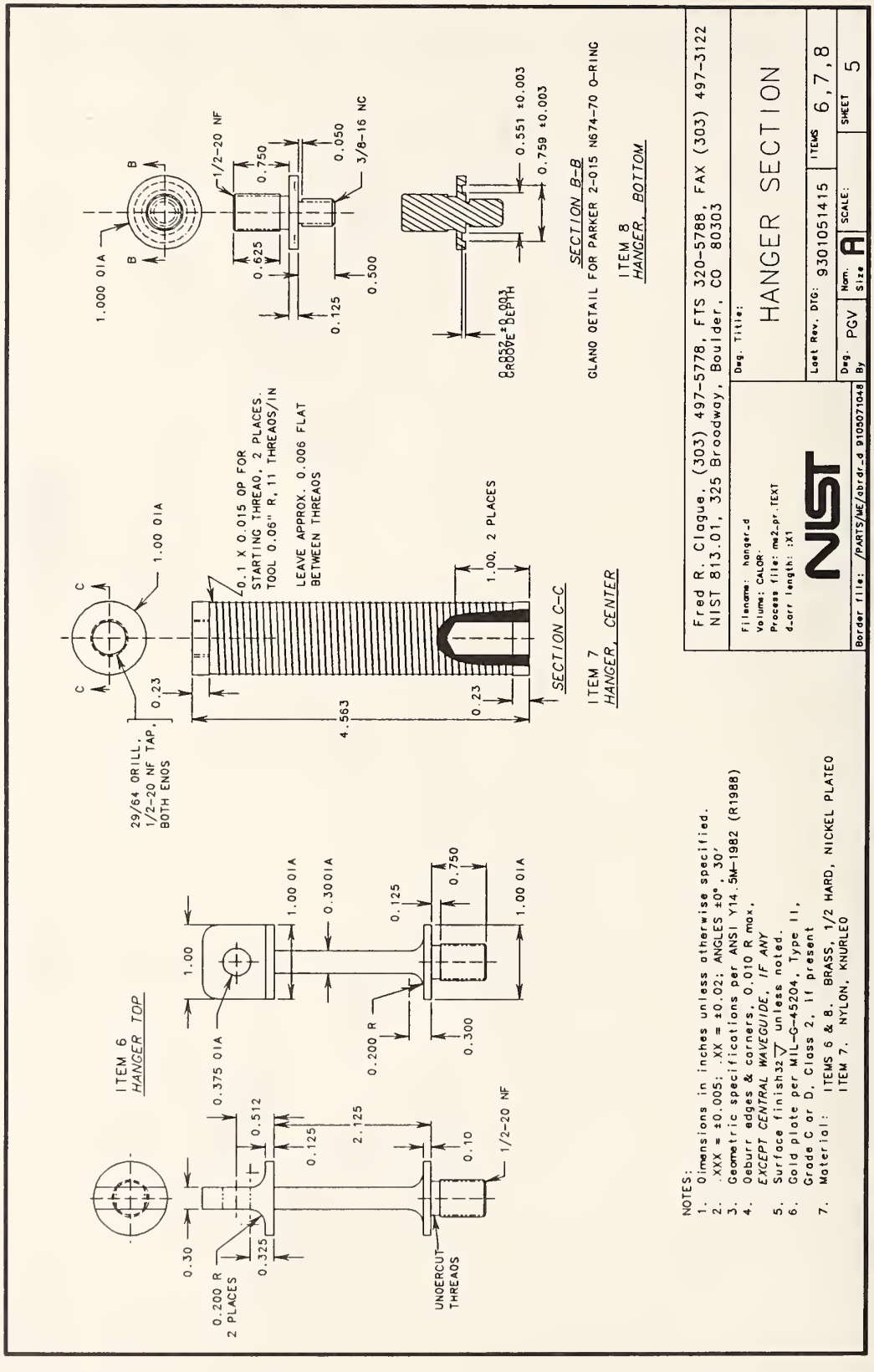
NOTES:
1. Dimensions in inches unless otherwise specified.
2. .XXX = ±0.005; .XX = ±0.02; ANGLES ±0°, 30'
3. Geometric specifications per ANSI Y14.5M-1982 (R1988)
4. Deburr edges & corners, 0.010 R max, EXCEPT CENTRAL WAVEGUIDE, IF ANY
5. Surface finish32 unless noted.
6. Gold plate per MIL-G-45204, Type II, Grade C or D, Class 2, if present
7. Material: ITEMS 6 & 8, BRASS, 1/2 HARD, NICKEL PLATED
ITEM 7, NYLON, KNURLED
ITEM 6
HANGER TOP
ITEM 7
HANGER, CENTER
ITEM 8
HANGER, BOTTOM
SECTION C-C
SECTION B-B
GLAND DETAIL FOR PARKER 2-015 N674-70 O-RING
29/64 DRILL, 1/2-20 NF TAP, BOTH ENDS
0.1 X 0.015 DP FOR STARTING THREAD, 2 PLACES. TOOL 0.06" R, 11 THREADS/IN
LEAVE APPROX. 0.006 FLAT BETWEEN THREADS
UNDERCUT THREADS
0.200 R 2 PLACES
1/2-20 NF
3/8-16 NC
0.551 ±0.003
0.759 ±0.003
0.852 ±0.003 DEPTH
Fred R. Clague, (303) 497-5778, FTS 320-5788, FAX (303) 497-3122
NIST 813.01, 325 Broadway, Boulder, CO 80303
Filename: hanger_d
Volume: CALOR:
Process file: ma2_pr.TEXT
d_arr length: :X1
Dwg. Title:
HANGER SECTION
Last Rev. DTG: 9301051415
ITEMS 6,7,8
Dwg. PGV
Nom. Size A
SCALE:
SHEET 5
Border file: /PARTS/ME/abrdr_d 9105071048 By

Figure B5. Hanger assembly for the cover.

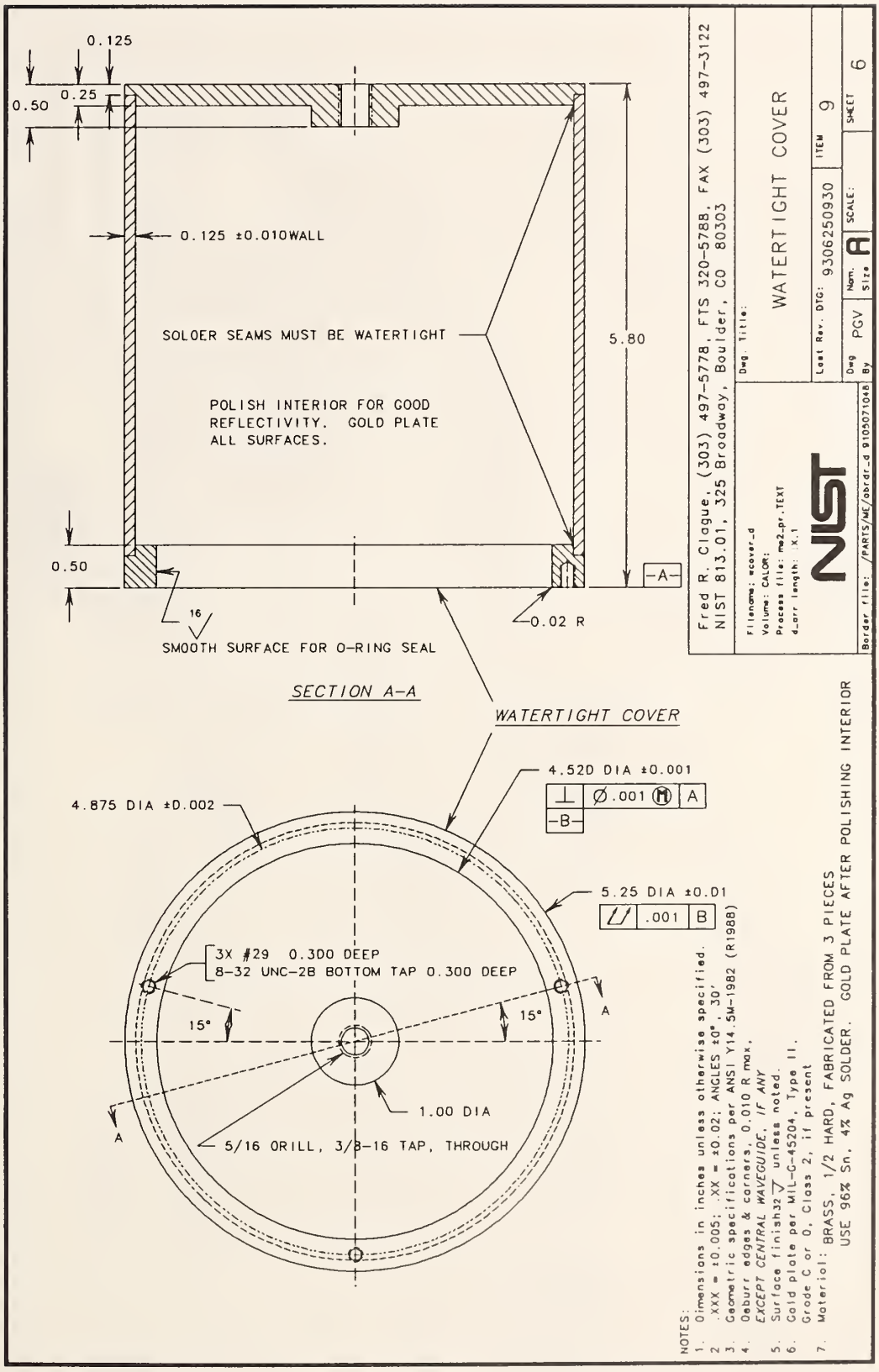

Figure B6. Watertight cover.

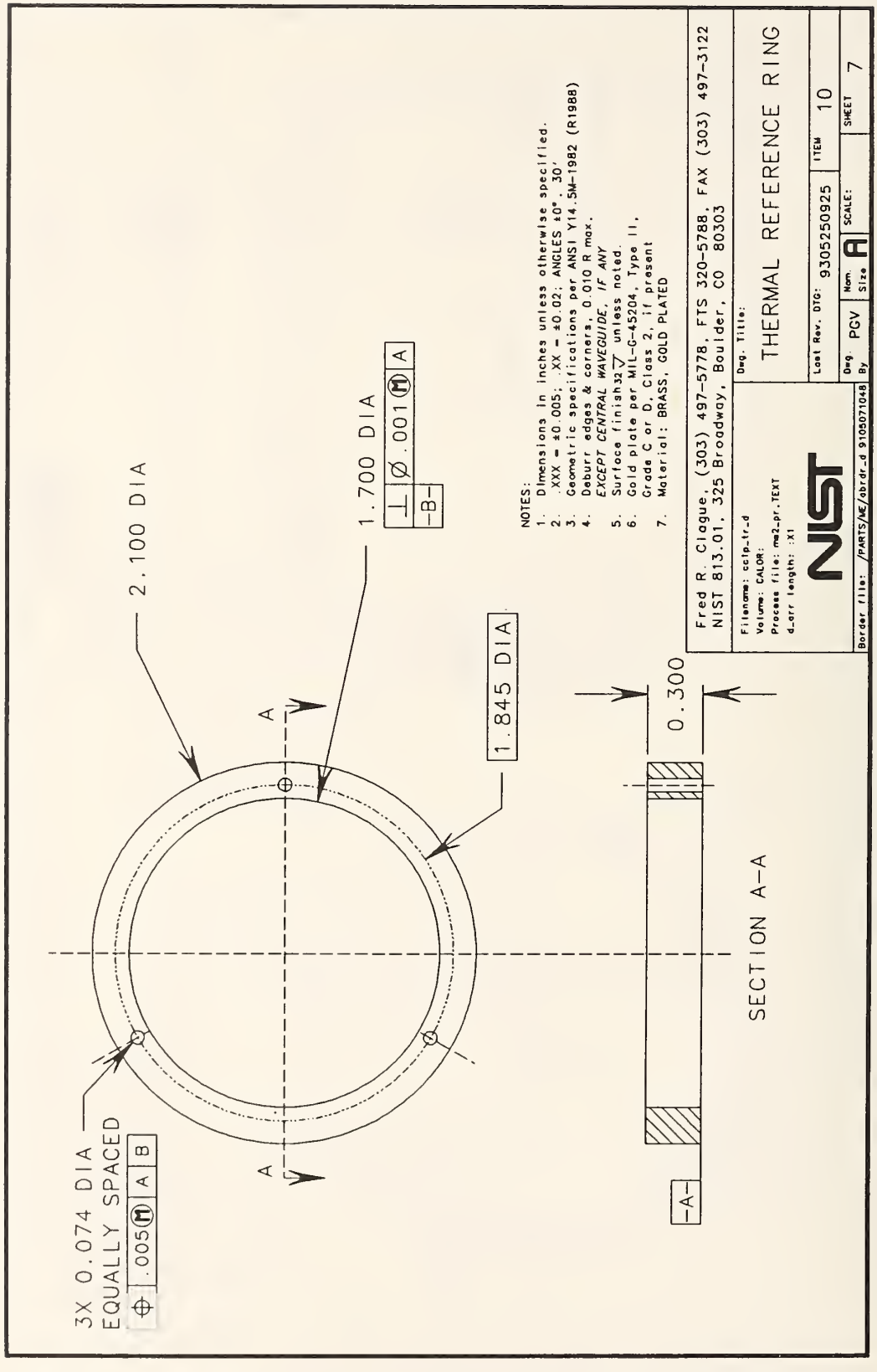

Figure B7. Thermal reference ring.

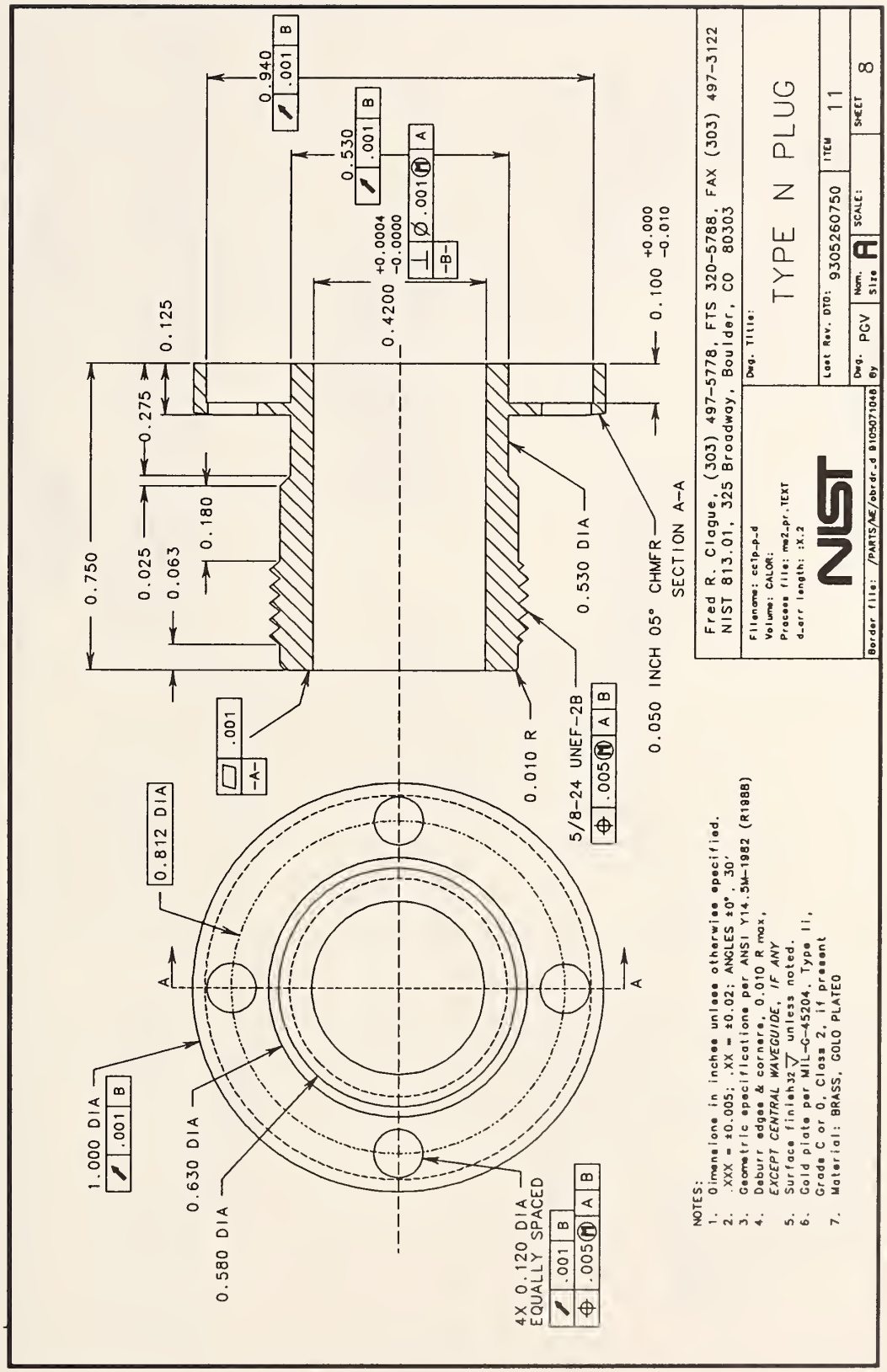

Figure B8. Type N connector and thermopile contact ring.

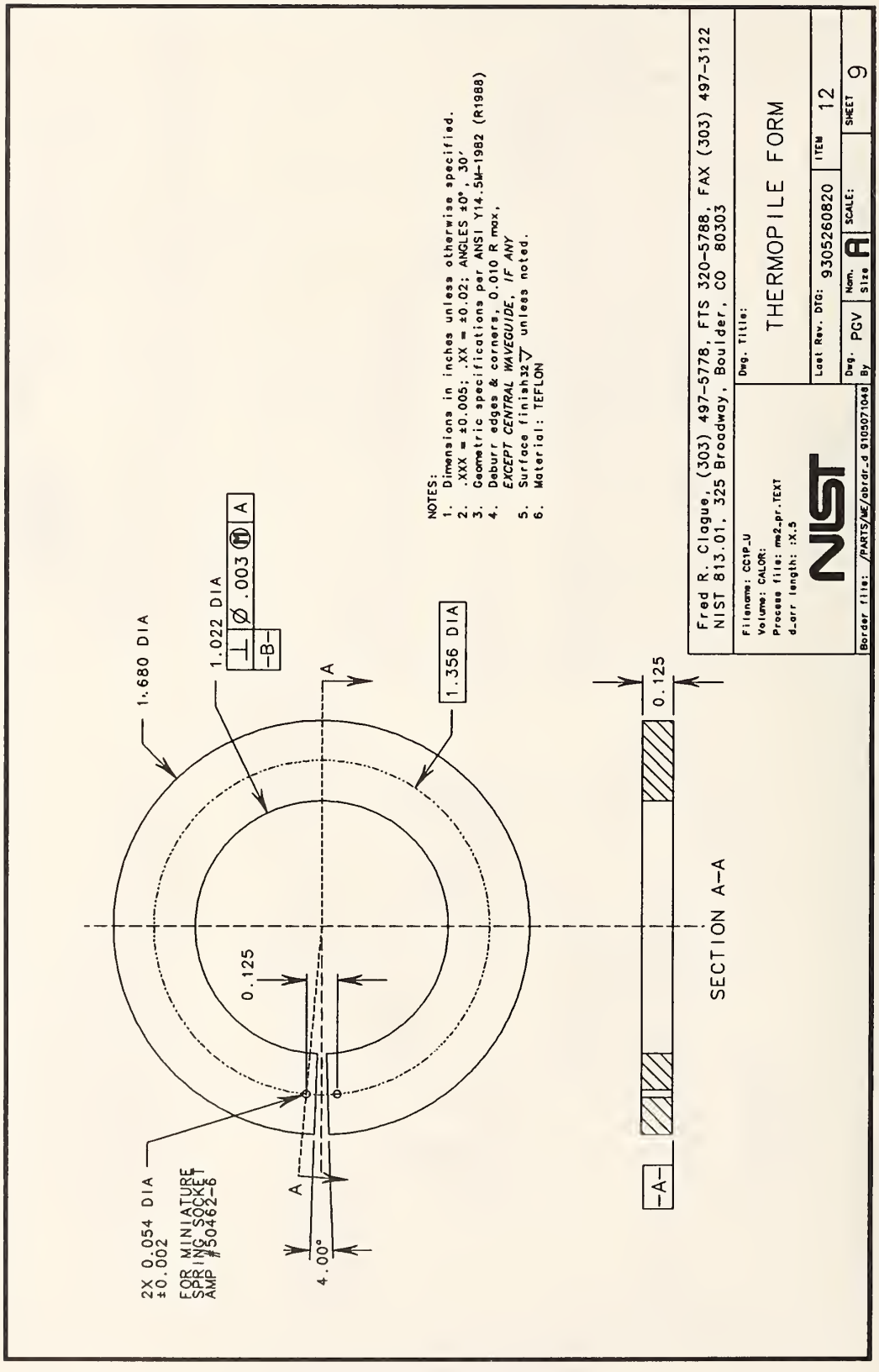

Figure B9. Thermopile form.

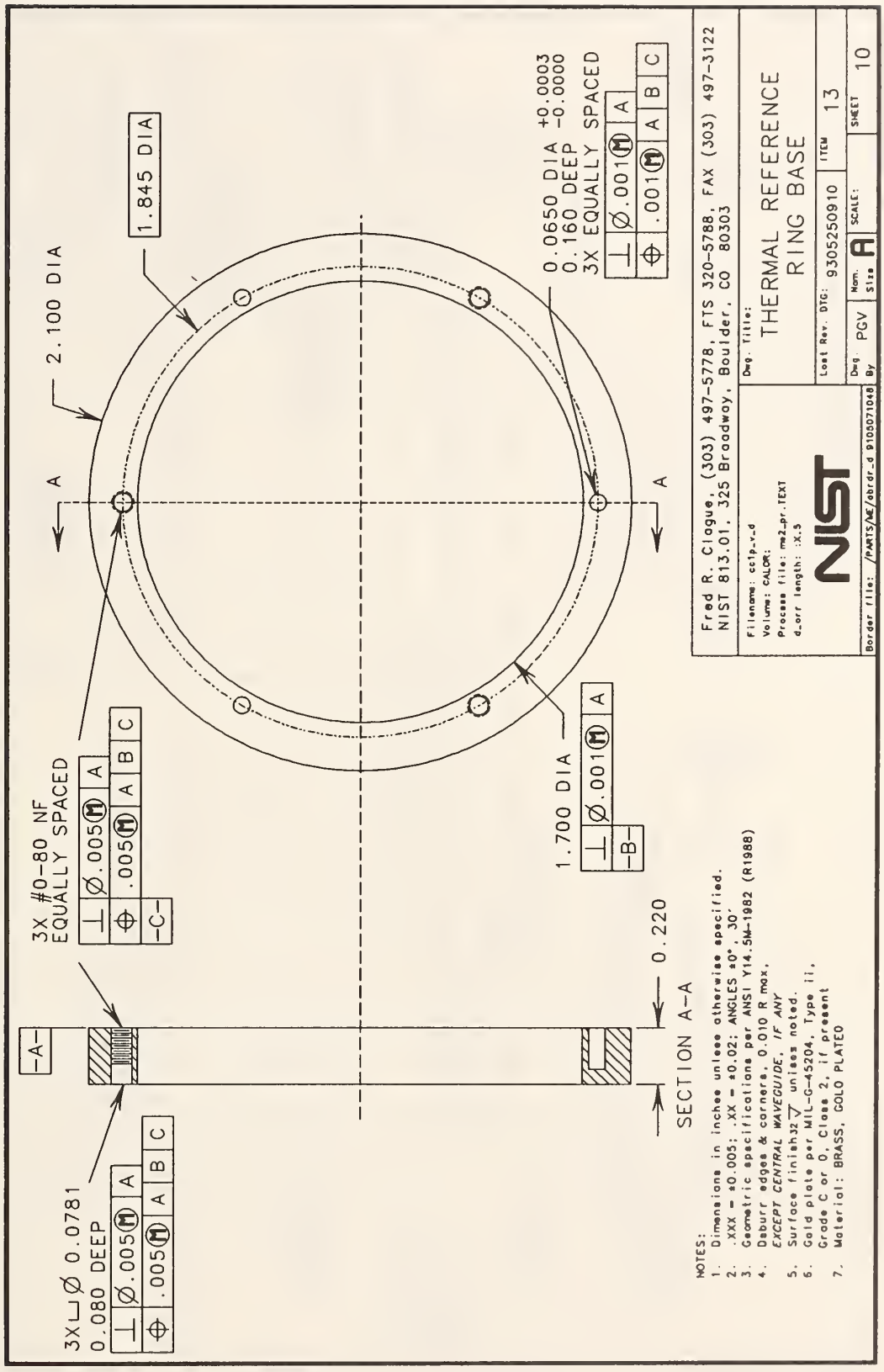

Figure B10. Base for thermal reference ring.

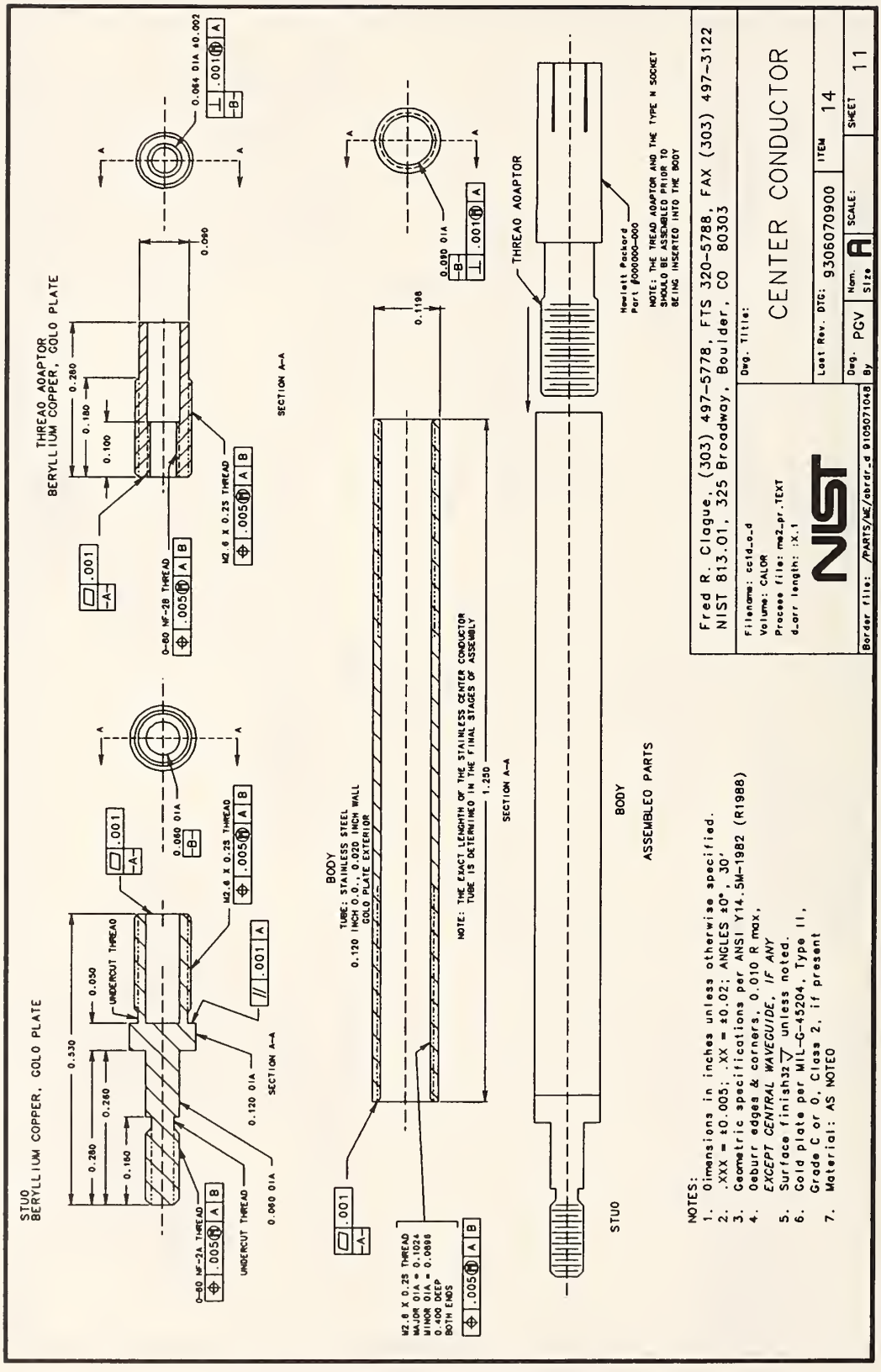
STUO
BERYLLIUM COPPER, GOLD PLATE
THREAD ADAPTOR
BERYLLIUM COPPER, GOLD PLATE
BODY
TUBE: STAINLESS STEEL
0.120 INCH O.D., 0.020 INCH WALL
GOLD PLATE EXTERIOR
NOTE: THE EXACT LENGTH OF THE STAINLESS CENTER CONDUCTOR TUBE IS DETERMINED IN THE FINAL STAGES OF ASSEMBLY
1.250
SECTION A-A
BODY
ASSEMBLED PARTS
STUO
THREAD ADAPTOR
Hewlett Packard
Part #0000000-000
NOTE: THE THREAD ADAPTOR AND THE TYPE N SOCKET SHOULD BE ASSEMBLED PRIOR TO BEING INSERTED INTO THE BODY
Fred R. Clague, (303) 497-5778, FTS 320-5788, FAX (303) 497-3122
NIST 813.01, 325 Broadway, Boulder, CO 80303
CENTER CONDUCTOR
Last Rev. DTG: 9306070900
ITEM 14
SHEET 11
Drg. By PGV
Nom. Size A
SCALE:
NOTES:
1. Dimensions in inches unless otherwise specified.
2. .XXX = ±0.005; .XX = ±0.02; ANGLES ±0°, 30'
3. Geometric specifications per ANSI Y14.5M-1982 (R1988)
4. Deburr edges & corners, 0.010 R max, EXCEPT CENTRAL WAVEGUIDE, IF ANY
5. Surface finish32 unless noted.
6. Gold plate per MIL-G-45204, Type II, Grade C or 0, Class 2, if present
7. Material: AS NOTED

Figure B11. Center conductor assembly.

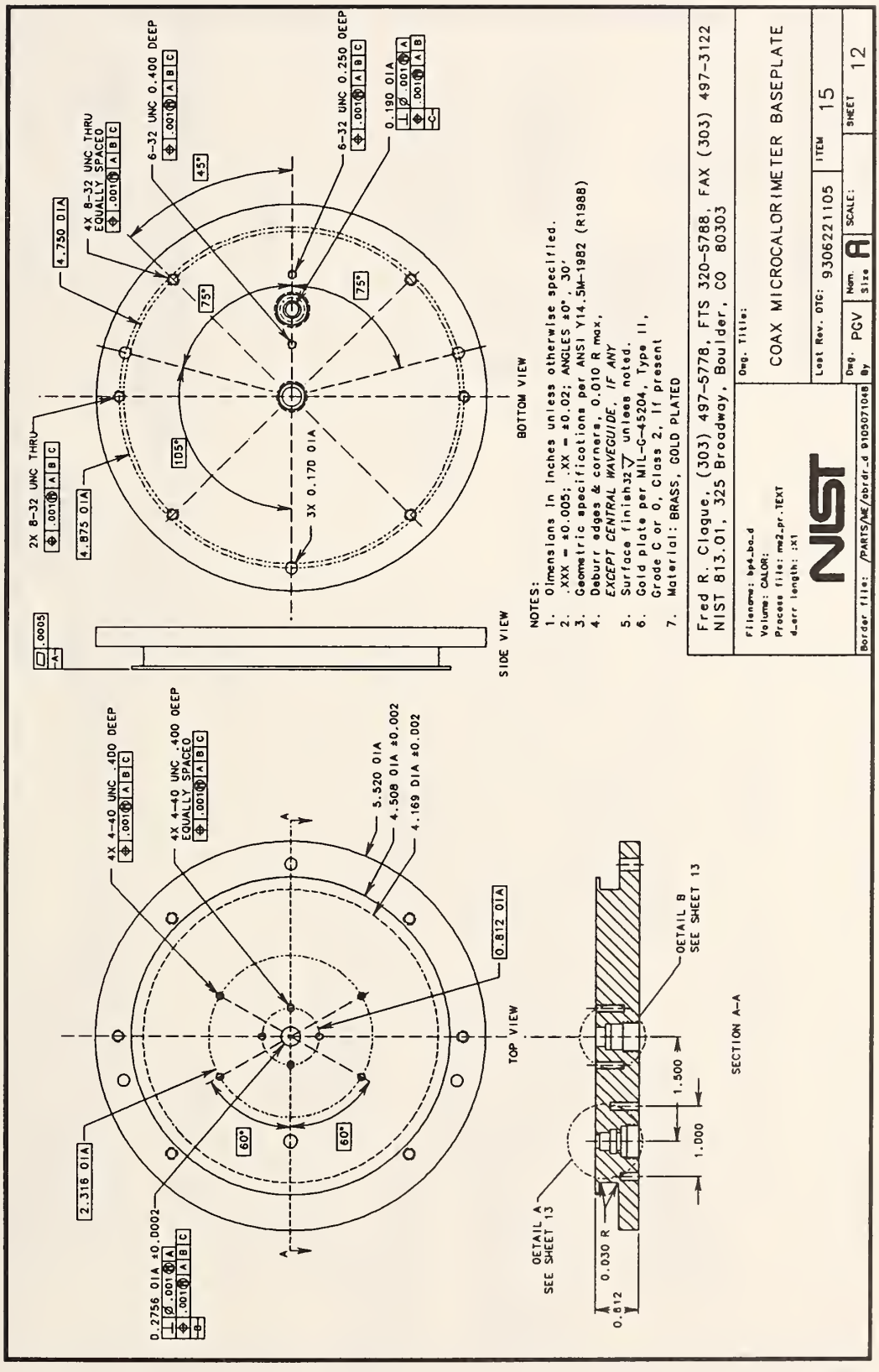

Figure B12. Microcalorimeter baseplate.

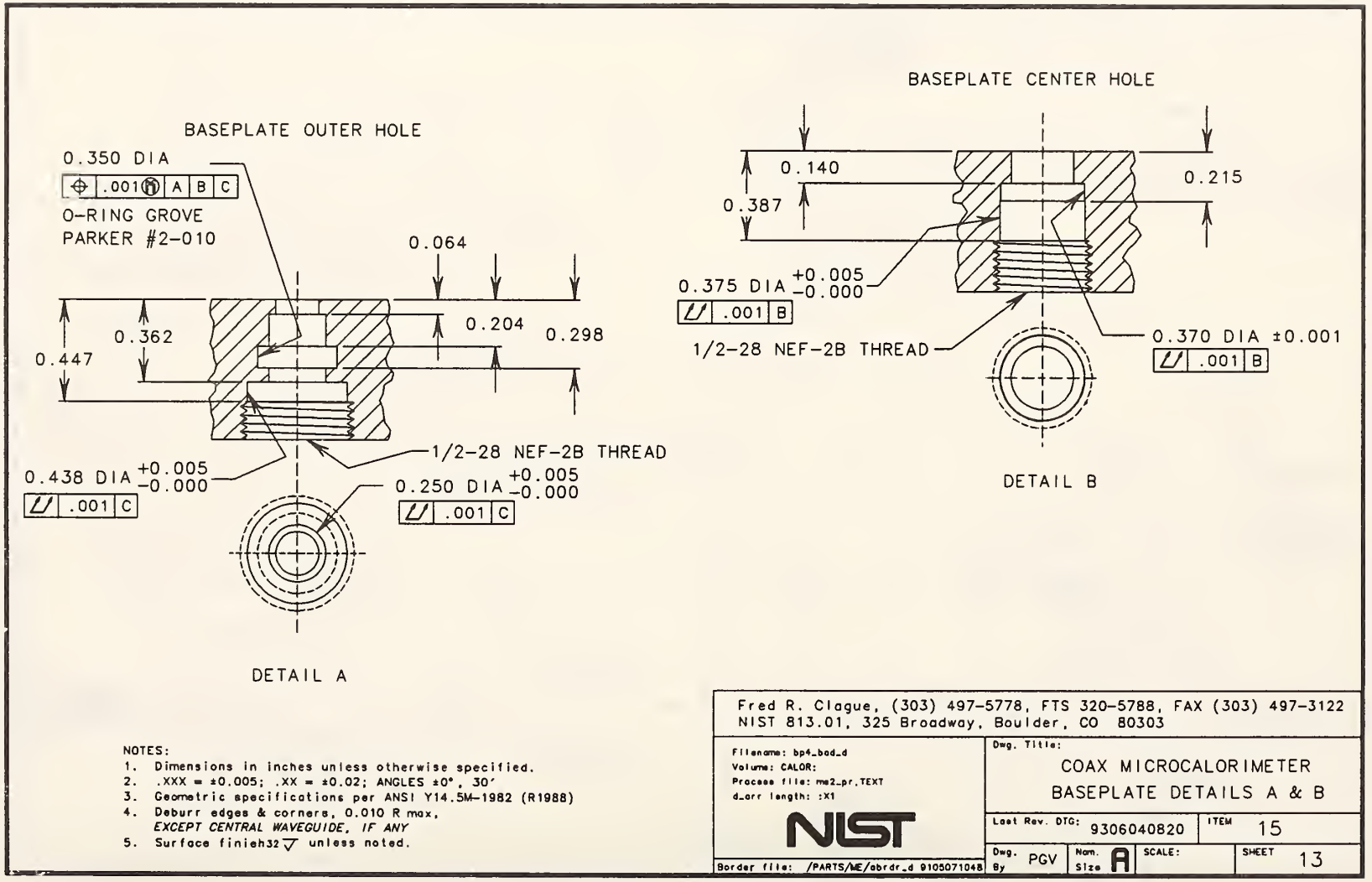

Figure B13. Microcalorimeter baseplate details.

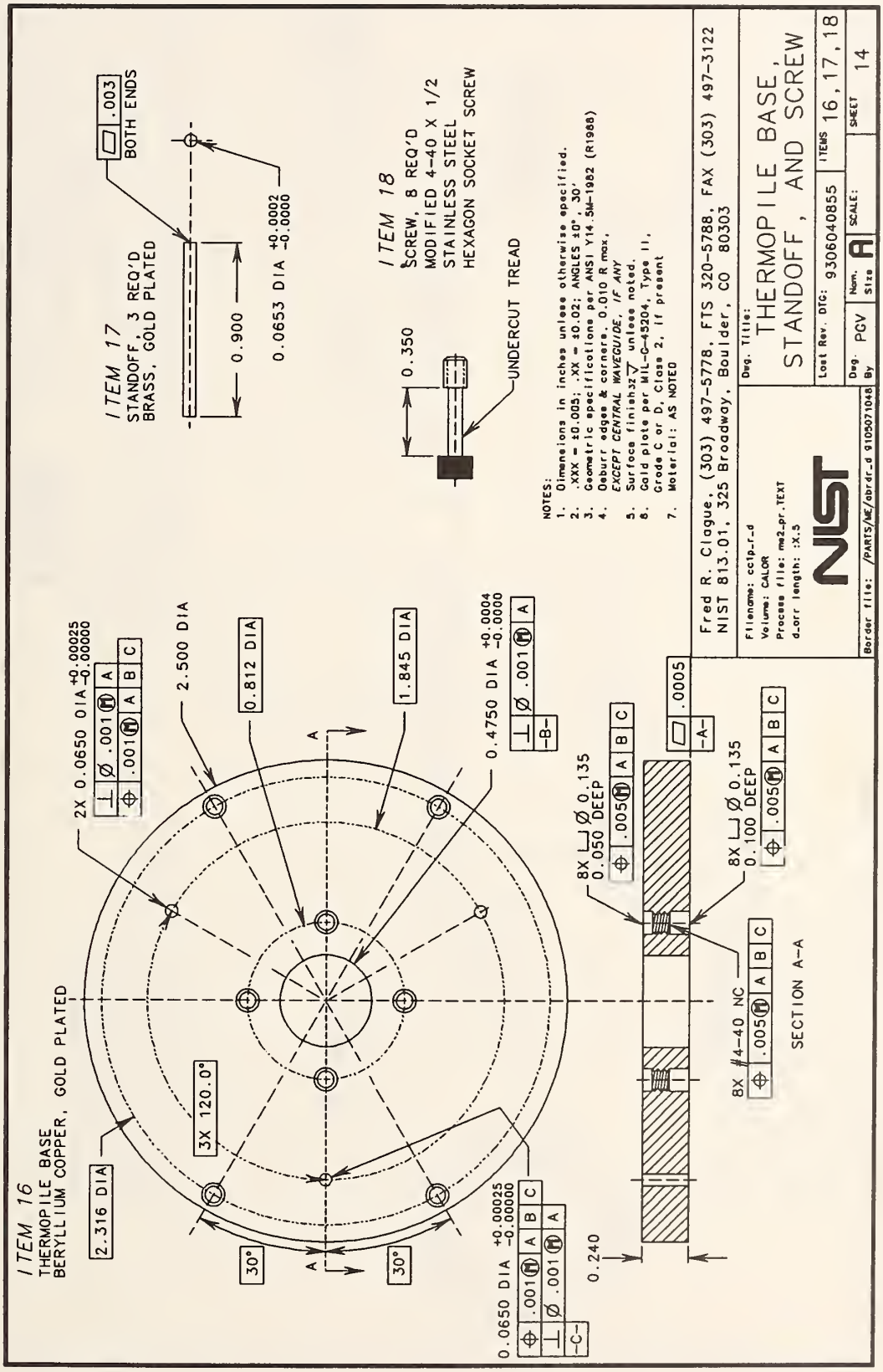

Figure B14. Thermopile baseplate, standoff, and screws.

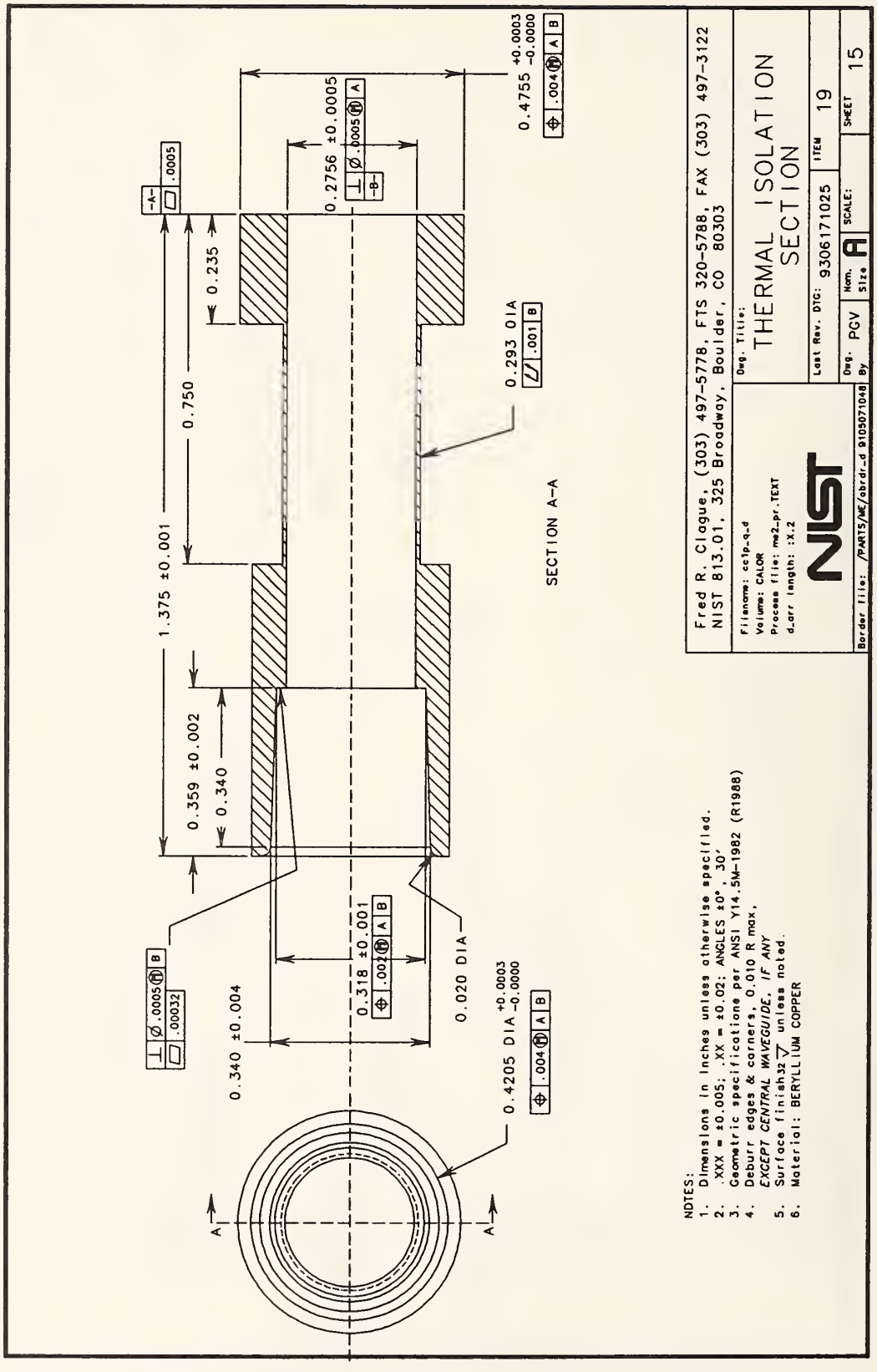

Figure B15. Type N connector and thermal isolation section.

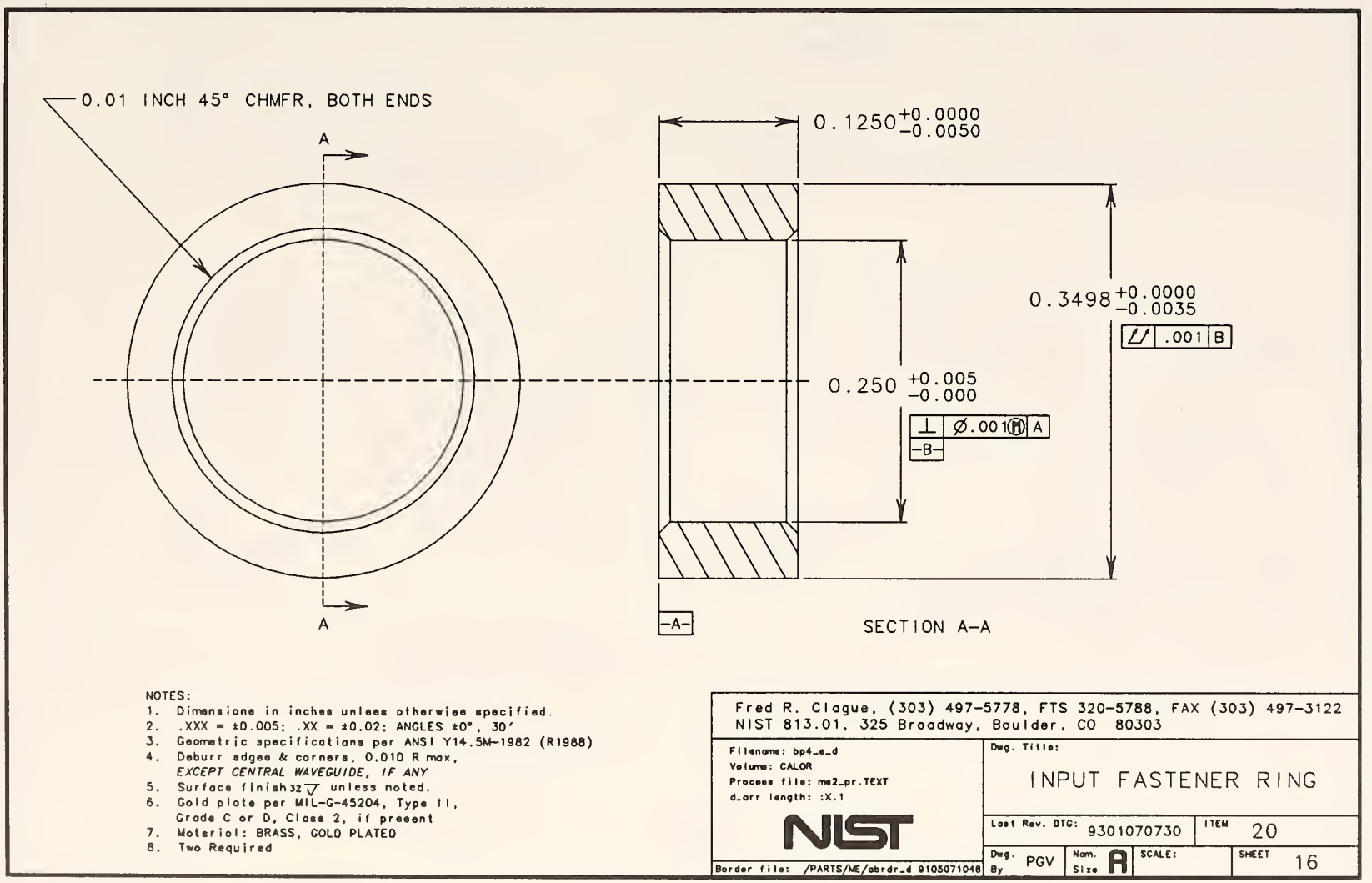
0.01 INCH 45° CHMFR, BOTH ENDS
A
A
0.1250 +0.0000 −0.0050
0.3498 +0.0000 −0.0035
⊥ .001 B
0.250 +0.005 −0.000
⊥ Ø.001 M A
-B-
-A-
SECTION A-A
NOTES:
1. Dimensions in inches unless otherwise specified.
2. .XXX = ±0.005; .XX = ±0.02; ANGLES ±0°, 30'
3. Geometric specifications per ANSI Y14.5M-1982 (R1988)
4. Deburr edges & corners, 0.010 R max, EXCEPT CENTRAL WAVEGUIDE, IF ANY
5. Surface finish 32 unless noted.
6. Gold plate per MIL-G-45204, Type II, Grade C or D, Class 2, if present
7. Material: BRASS, GOLD PLATED
8. Two Required
Fred R. Clague, (303) 497-5778, FTS 320-5788, FAX (303) 497-3122
NIST 813.01, 325 Broadway, Boulder, CO 80303
Filename: bp4_e_d
Volume: CALOR
Process file: ms2_pr.TEXT
d_arr length: :X.1
NIST
Border file: /PARTS/ME/abrdr_d 9105071048
Dwg. Title:
INPUT FASTENER RING
Last Rev. DTG: 9301070730
ITEM 20
Dwg. By PGV
Nom. Size A
SCALE:
SHEET 16

Figure B16. Fastener ring for input lines.

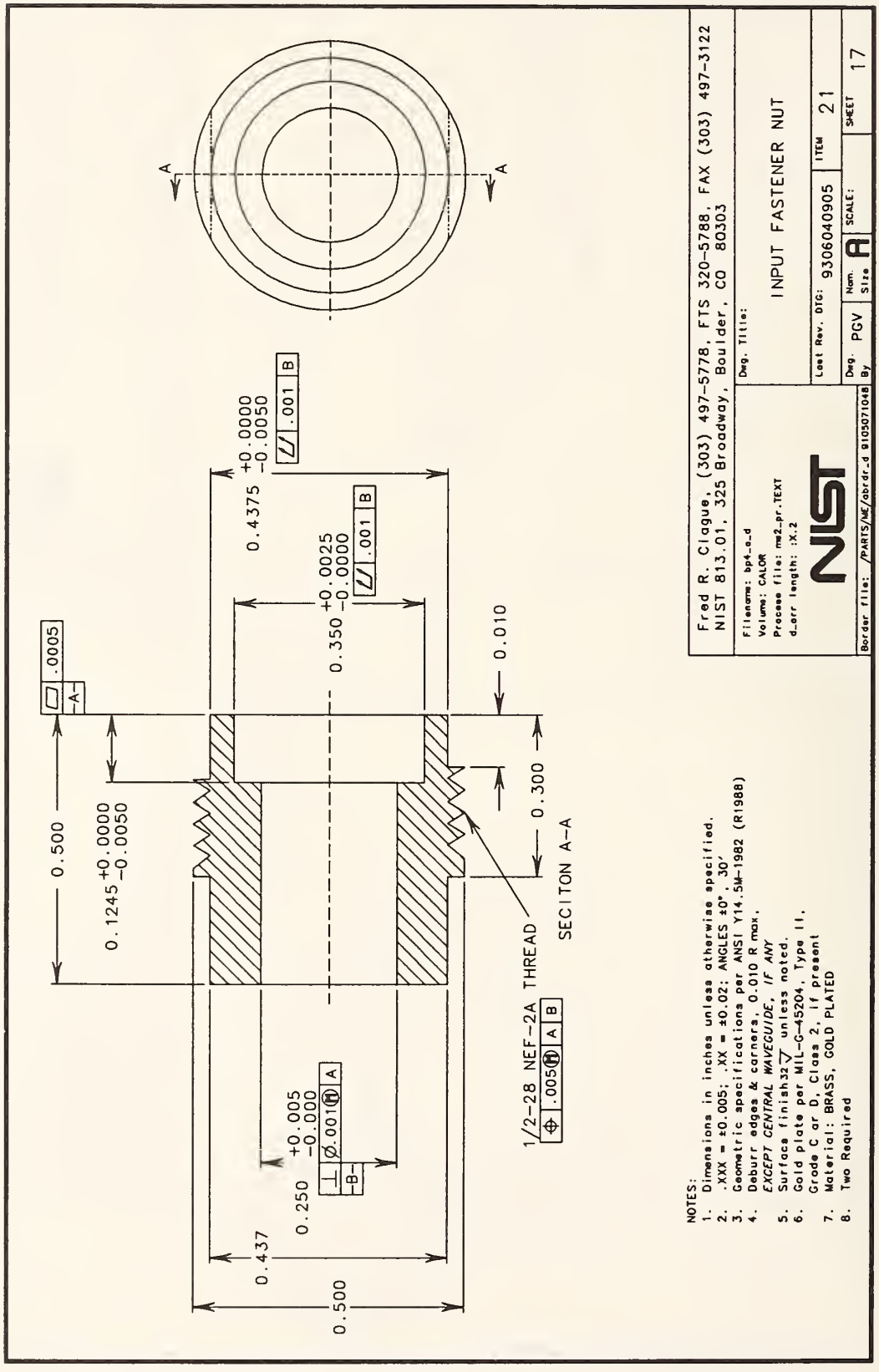

Figure B17. Fastener nut for input lines.

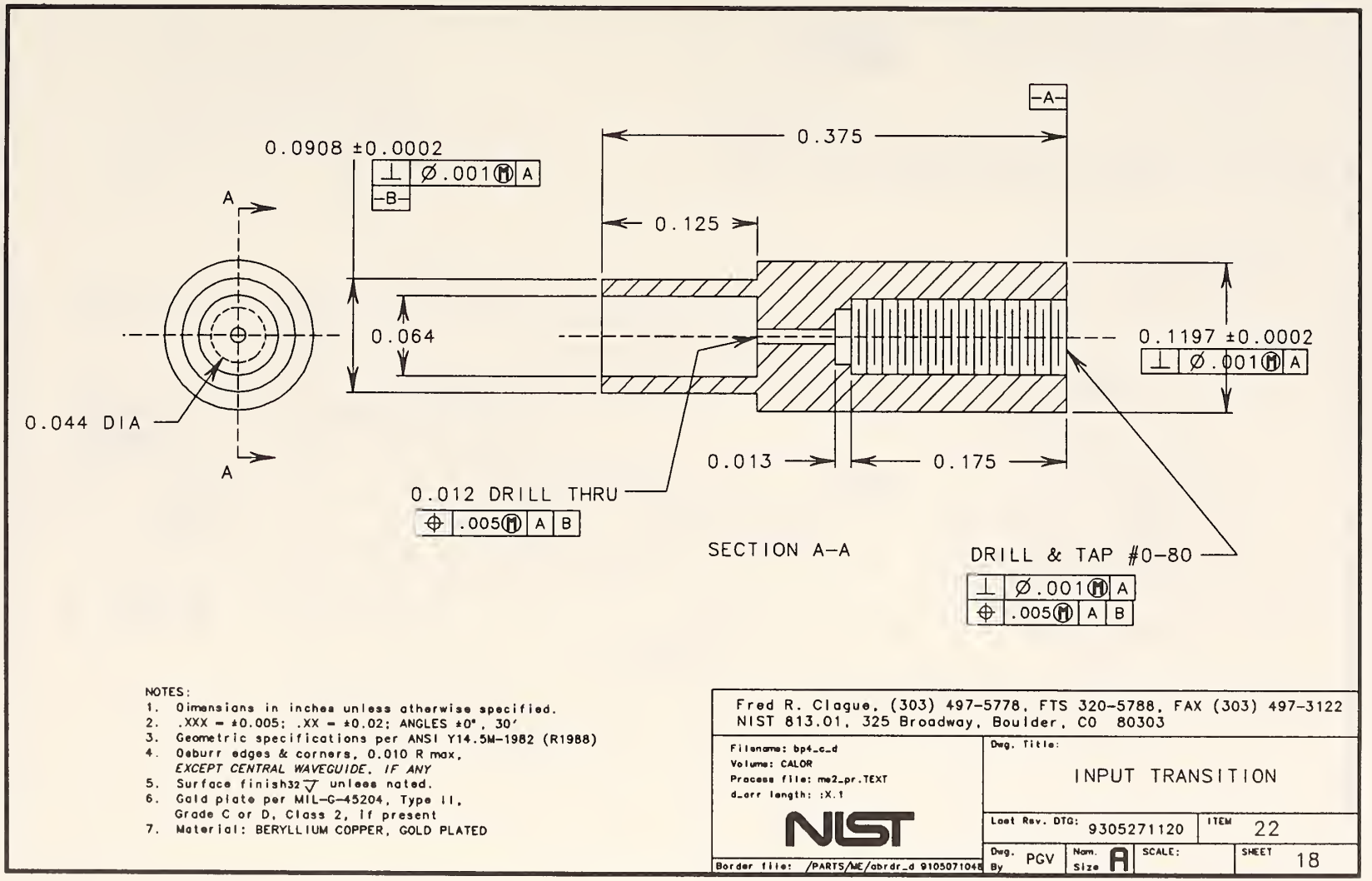

Figure B18. Center conductor transition.

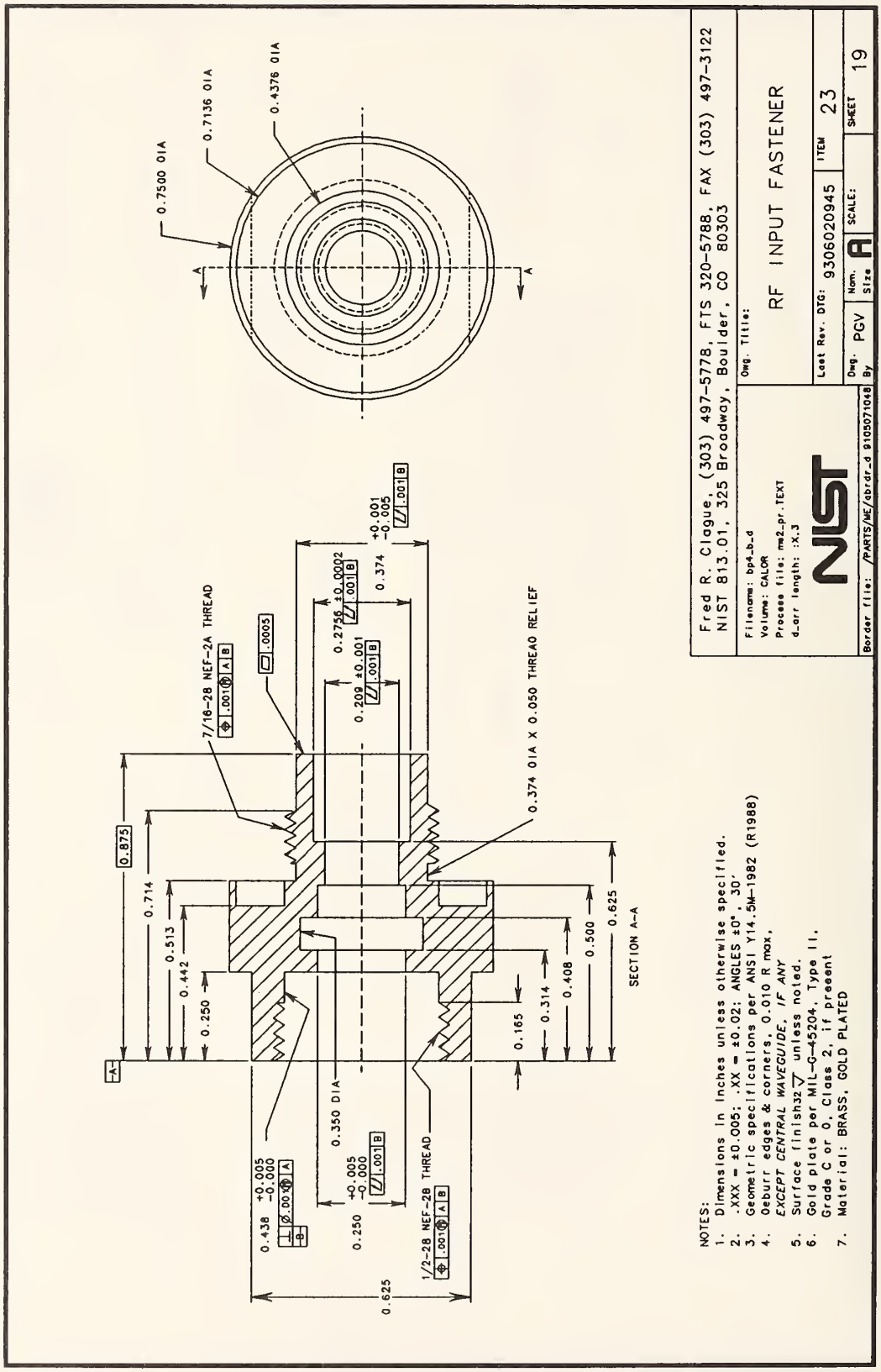

Figure B19. Fastener for coaxial rf input.

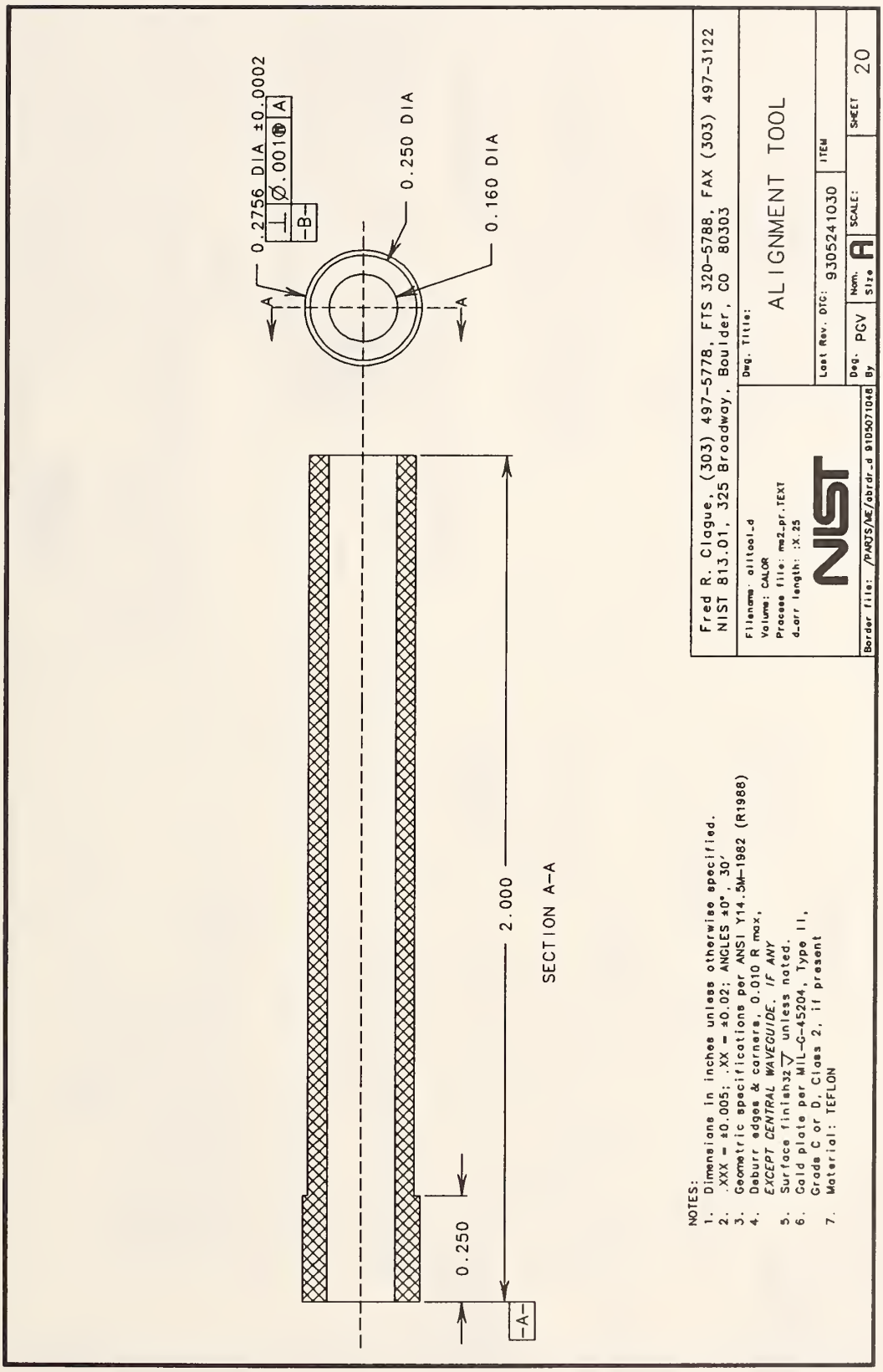

Figure B20. Alignment tool.

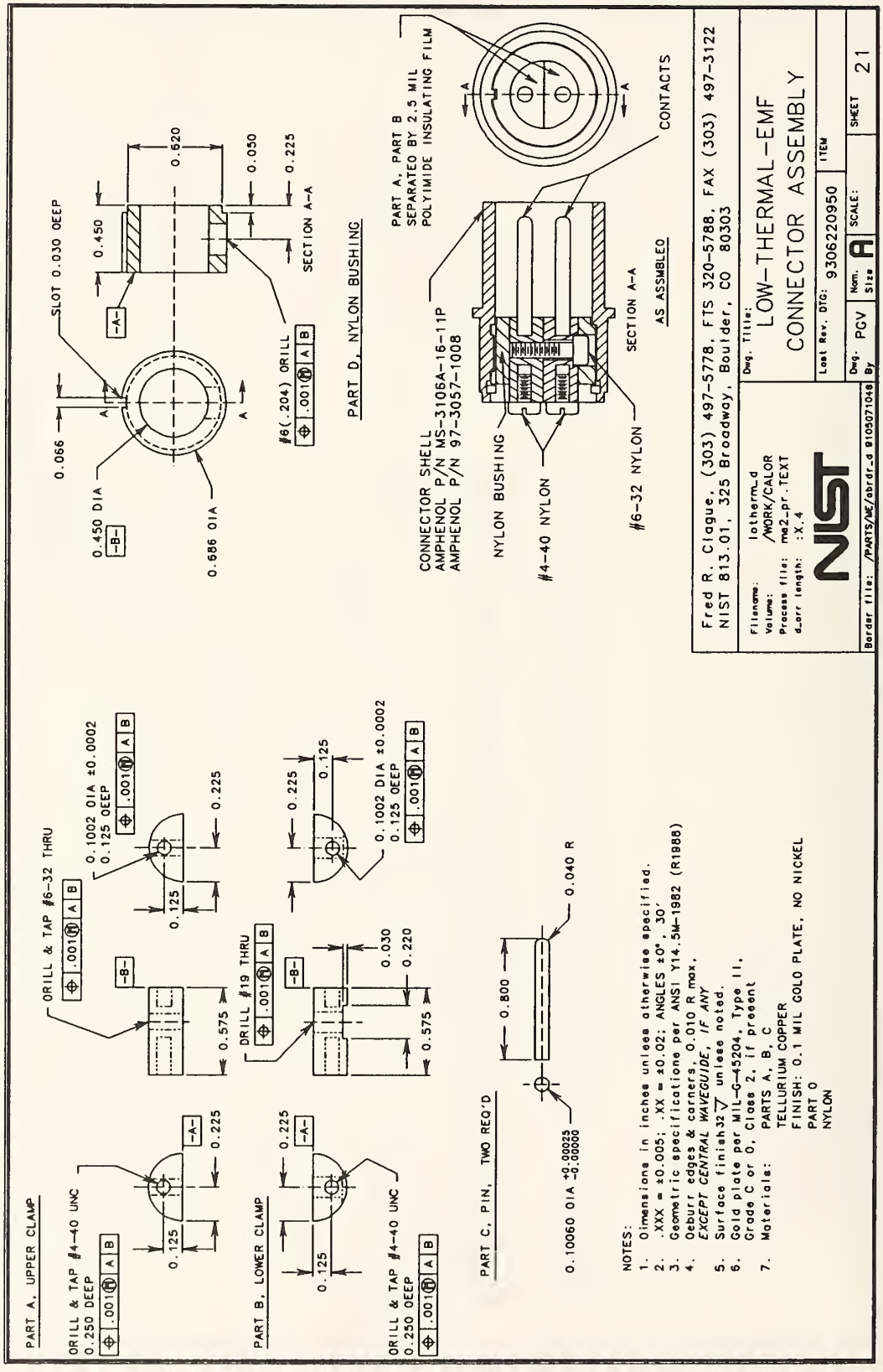

Figure B21. Low-thermal-EMF connector.

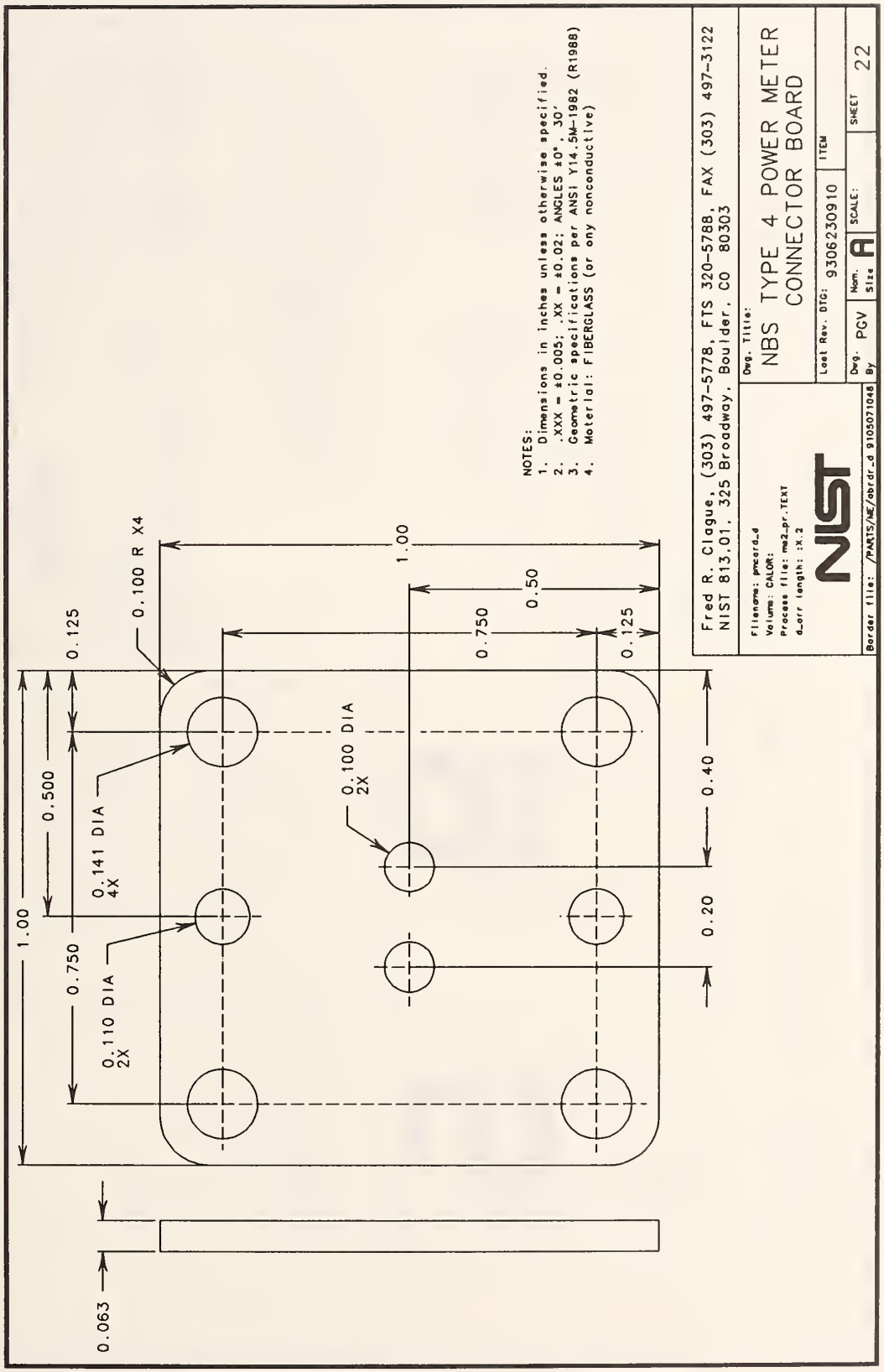

Figure B22. NIST Type IV power meter connector part.

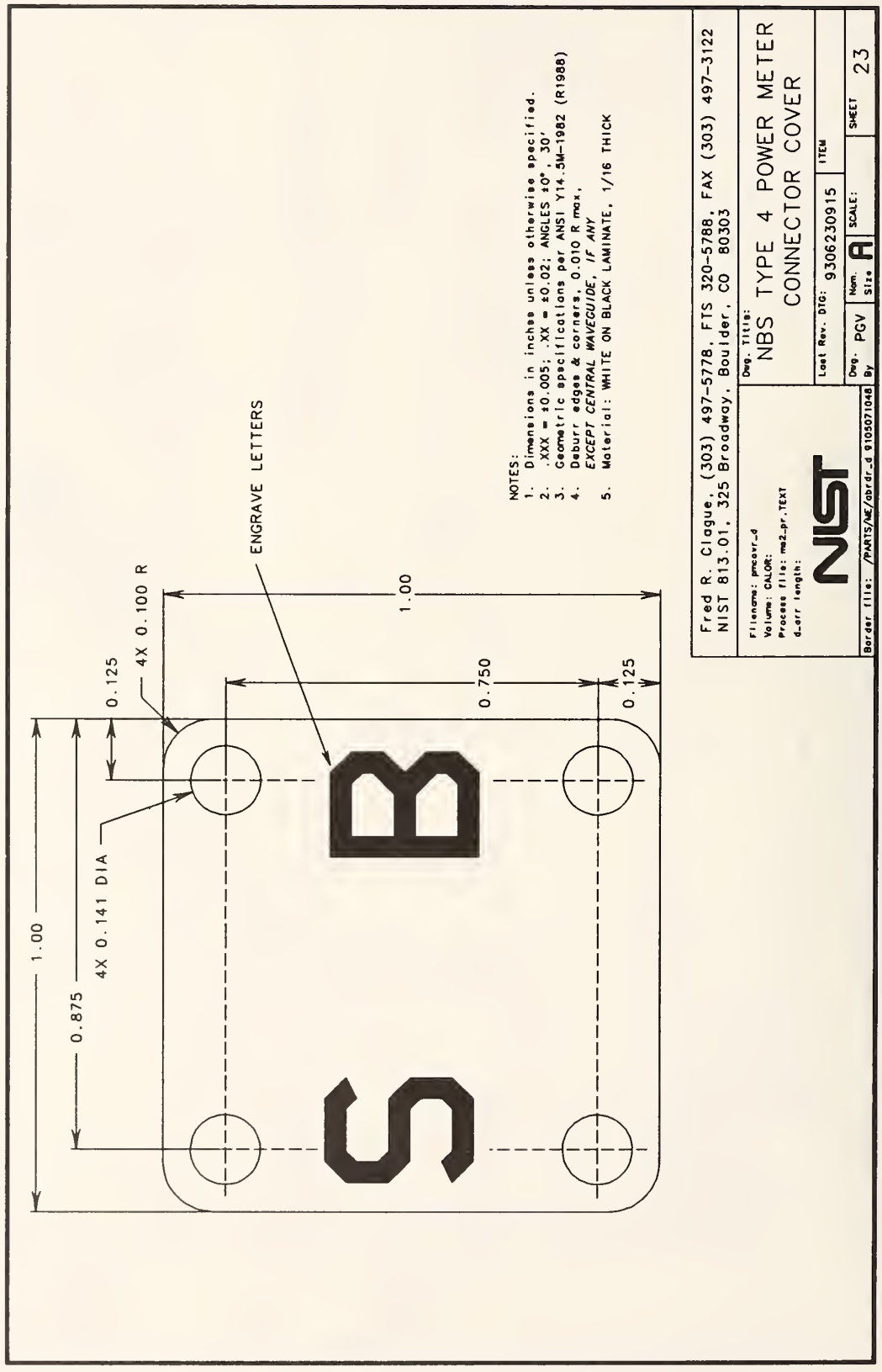

Figure B23. NIST Type IV power meter connector part.

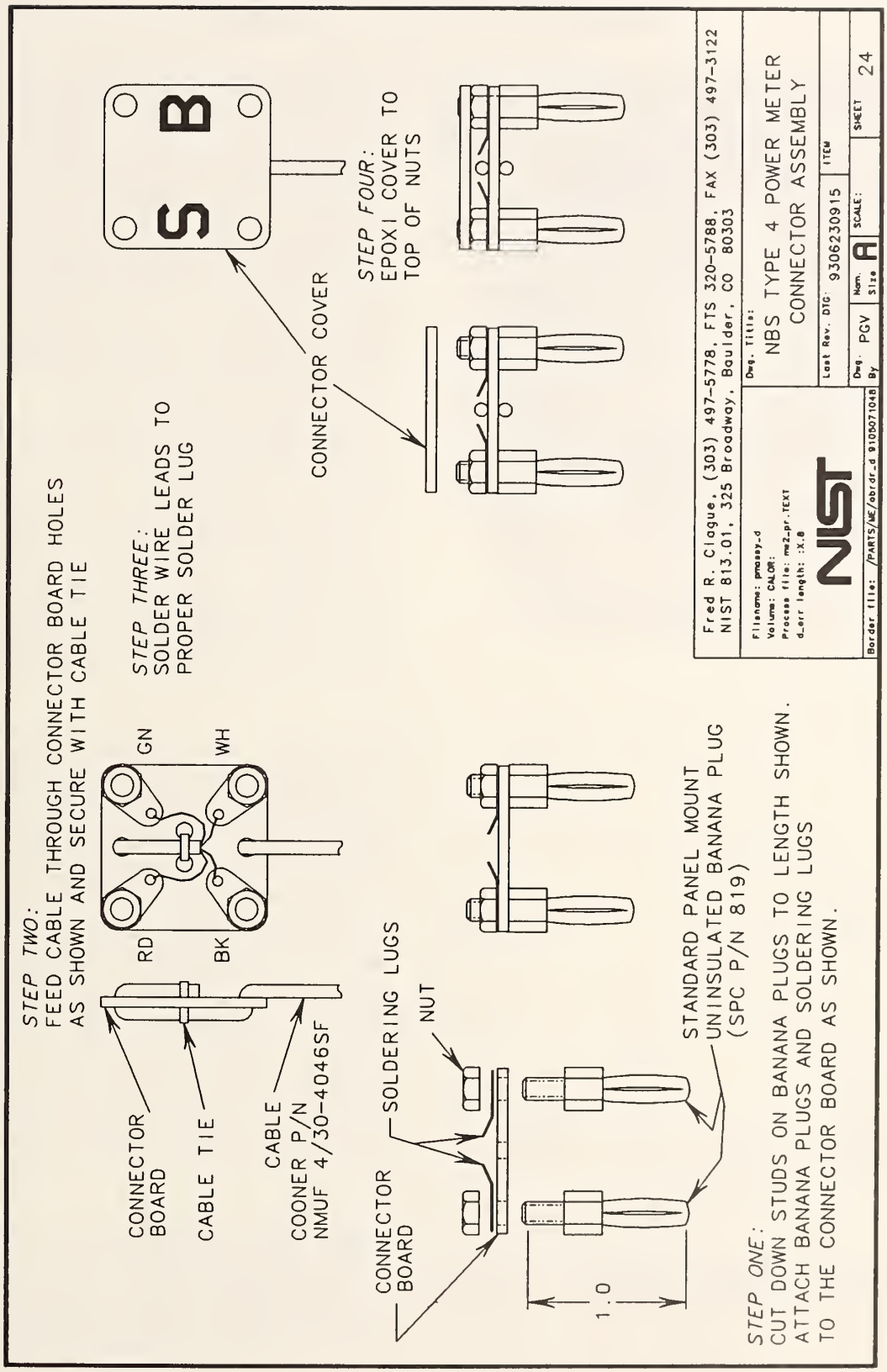

Figure B24. NIST Type IV power meter connector assembly.

APPENDIX C. New Thermopile Assembly

The body of this report documents the design and construction of the original NIST coaxial microcalorimeters. The Type N version of the microcalorimeter has been modified with a new thermopile assembly. The thermopile output voltage is now over an order of magnitude higher than the original design. This increased sensitivity allows coaxial reference standards to be measured at less microwave power than the previous 10 mW minimum. Measurement of the effective efficiency of a CN transfer standard at 1 mW is now possible, producing a low power calibration with a slightly increased uncertainty. Also, a measurement at 1 mW and again at 10 mW provides a way to determine the transfer standard nonlinearity which is caused by the dual-element substitution error [C1]. Additionally, with the higher output, thermal emf's are of less concern.

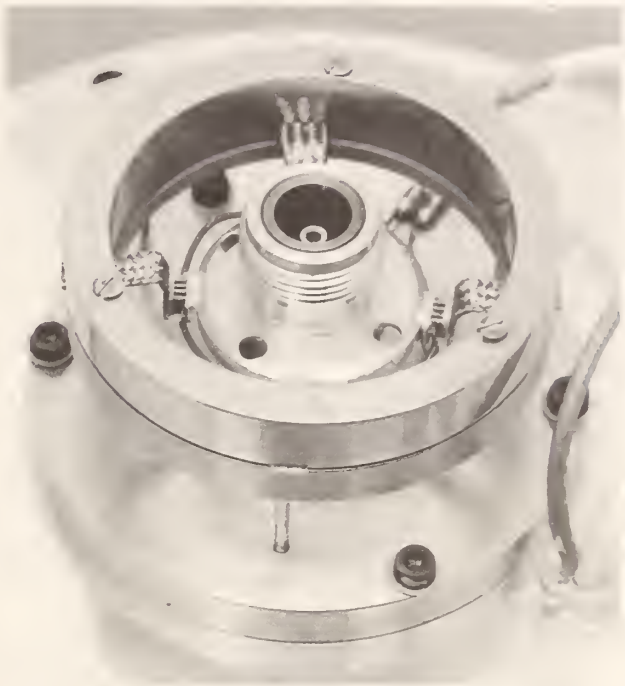

Figure C1. Coaxial microcalorimeter

Figure C1 shows the Type N microcalorimeter with the new thermopile assembly. The thermopile consists of four commercially obtained modular heat pumps electrically connected in series and mounted radially between the outer conductor and the thermo-pile reference ring. The copper braid provides the thermal path from the small heat pump to the ring. Other than replacing the original thermopile with the new, the mechanical structure of the microcalorimeter is unchanged. Thus the previously determined calorimetric equivalence correction factor also remains valid.

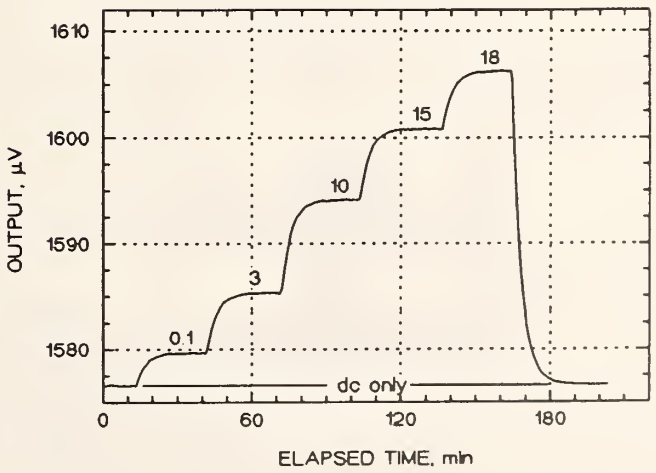

Figure C2. Thermopile output versus time for five frequencies (in GHz).

Figure C2 is the equivalent of the earlier figure 1.2 and shows the thermopile output for five frequencies. This output voltage is almost 15 times greater than with the original thermopile.

An example of the effective efficiency measurement as a function of power is shown in figure C3. Four repeated measurements and their average are plotted. The observed change from 1 mW to 10 mW is about 0.1 percent.

Figure C4 is similar to figure 3.5 and is a top and side view of the modified thermopile assembly. Figure C5, the equivalent of a portion of figure 3.2. shows the original plus the new parts which are referenced and described in table C.1. This table, which adds to the list found in table A.1, appendix A, identifies the parts and a manufacturer.

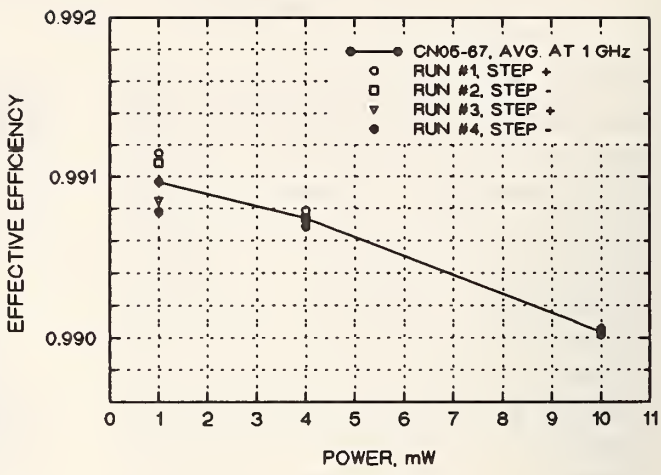

Figure C3. Effective efficiency of the CN mount at 1 GHz as measured at three power levels.

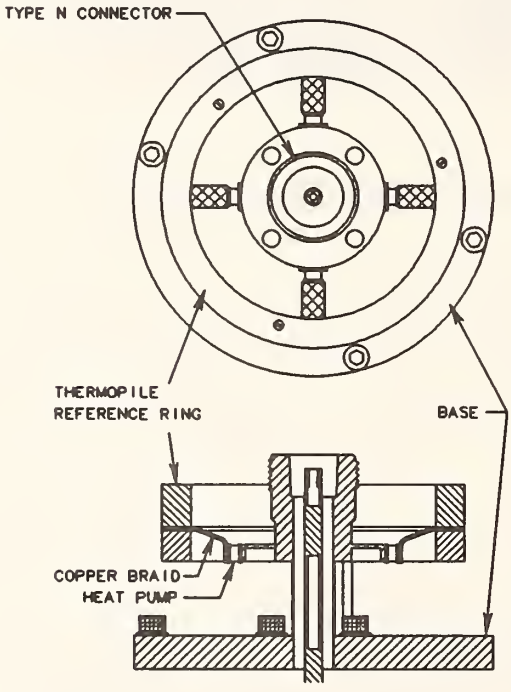

Figure C4. Top and cross-sectional views of the modified thermopile assembly.

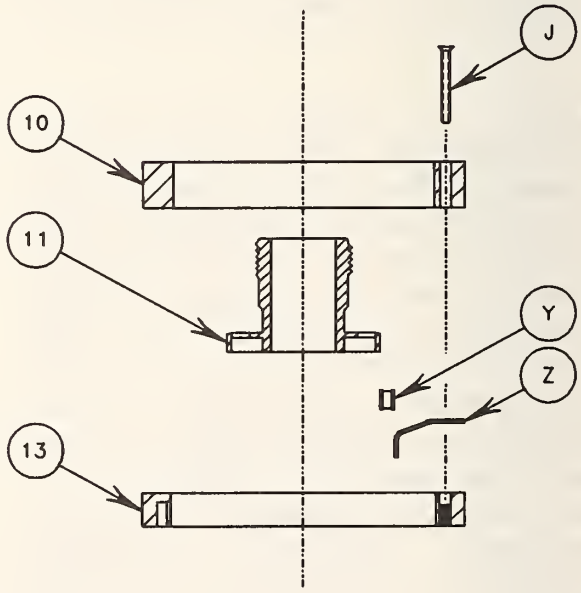

Figure C5. Exploded cross section of the modified thermopile assembly.

Table C.1. Commercial parts list		
Part ID	No. needed	Part No, Description, Manufacturer
Y	4	FC 0.45-8-05L thermoelectric (Peltier) heat pump Melcor, Trenton NJ 08648 (609) 393-4178
Z	4	No 15-5 "Chem-Wik", 0.150" X 1" piece of untinned copper braid Chemtronics Inc., Hauppauge, NY 11787
AA	--	Solder, BiSn (58% Bismuth, 42% Tin) 138 C eutectic solder Indium Tin Corp. of America, Utica NY 13503 (315) 797-1630
BB	--	EG-8050-HC, thermally conductive epoxy (Ag-filled) A. I. Technology Inc., Princeton, NJ 08543 (609) 882-2332

The following describes the assembly and installation of the new thermopile. It is intended as a rough guide only and should be studied carefully before starting the process. Items in parentheses are the component and part identifications as shown in figure C5 and table C.1. In making the thermopile change, it is assumed that the original thermopile as described in section 3.2.2 has been removed or was never installed. It is also assumed that the thermopile reference ring base (13) and the reference ring (10) are not installed. If the base is already in place, the heat pumps can be put in without removing it; it is just more difficult.

1. If using a copper braid made for solder wicking, the flux must be first be completely removed using a suitable solvent.

2. Cut the braid to the lengths needed and form to the approximate final shape.

WARNING: The semiconductor materials used in heat pump construction are structurally very weak. Avoid placing any torsional or shearing stresses on the heat pumps. Touching the crystals with a tool may fracture them.

3. Remove all leads, if any, from the heat pumps. Replace with #26 stranded hookup wire with thin insulation, for flexibility. Use only one lead per pump for three of the pumps, as the pumps will eventually be connected in series. Use solder and flux available from the heat pump manufacturer. The heat pump is assembled with a bismuth-tin eutectic solder melting at about 136°C, available from the heat pump manufacturer. An active zinc chloride-based flux such as Alpha Metals flux 200L may be used.

4. Saturate a small area of one end of each piece of copper braid with thermally-conductive epoxy and attach to the smaller plate on each heat pump. Pay attention to orientation, so that proper polarity is maintained. The braid must point "up" and the leads "down" on each pump. Small spring clips may be used to clamp the braid to the heat pump, taking great care not to overstress the part. Use only enough force to hold close contact between the braid and the heat pump.

5. Cure the epoxy using a thermostatically-controlled hot plate or enclosure. The cure temperature must remain below 100°C to avoid melting any of the solders.

6. Complete the lead attachment by connecting all pumps in series, such that the thermoelectric outputs all add.

7. Bond the larger plate on each of the heat pumps to the lower flange of item (11) with thermally-conductive epoxy. A rubber band may be used to hold them during the cure cycle, or, they may be bonded one at a time with spring clips.

8. Install the thermal reference ring (13).

9. Clamp the four copper braids between the base (13) and the reference ring (10) and trim off any excess braid.

Reference

[C1] Engen, G.F. A dc-rf substitution error in dual-element bolometer mounts. IEEE Trans. Instrum. Meas. IM-13: 58-64; 1964 June-September.

*U.S. GOVERNMENT PRINTING OFFICE:1993-774-025/89043

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Boulder, Colorado 80303-3328

Official Business
Penalty for Private Use, $300